Composability in Current and Future Sensor Simulations

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CECOM Bottom Line: The Warfighter

Distribution Statement: Approved for public release; distribution is unlimited.

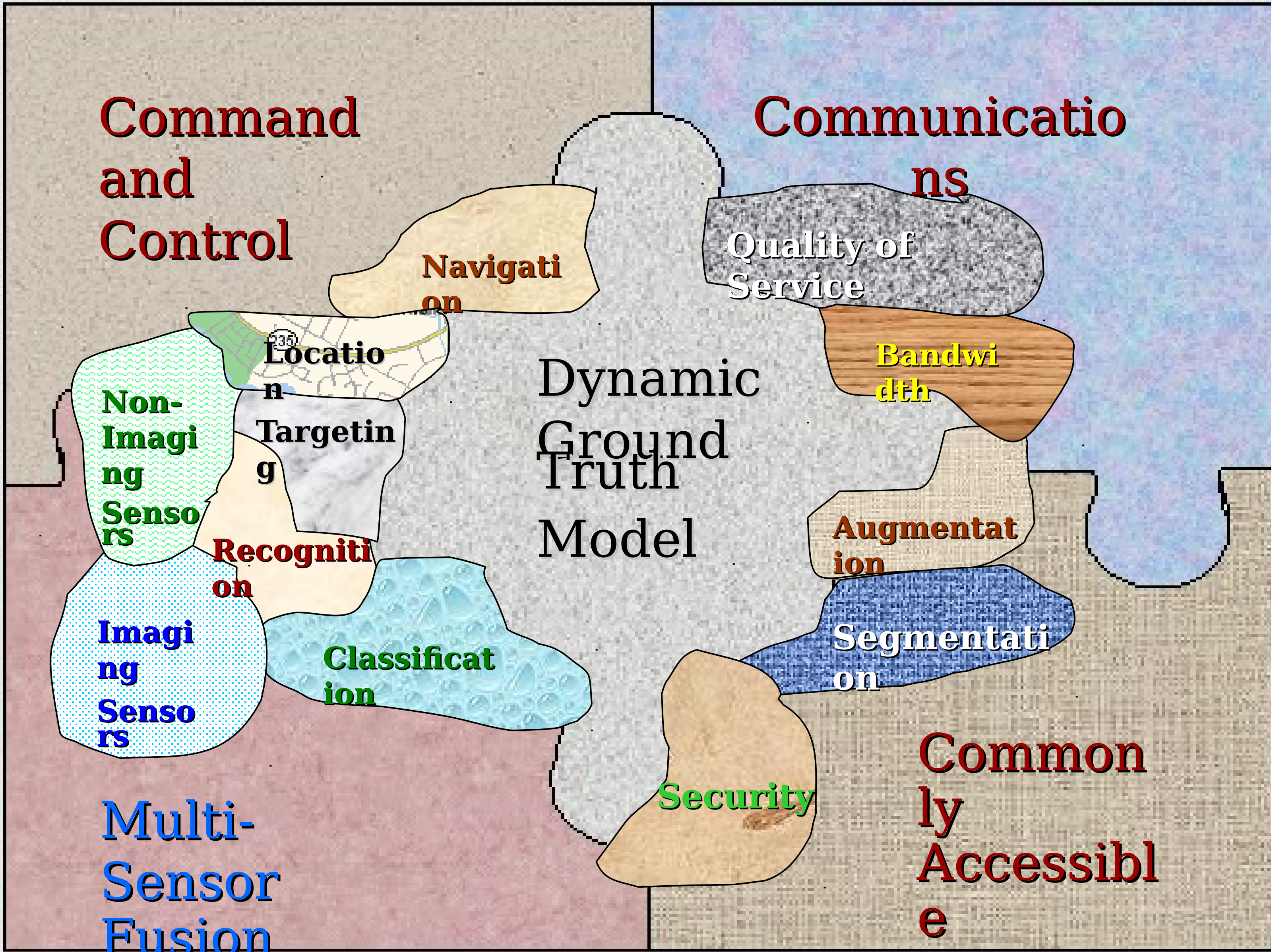
Outline

- Vision
- Problem Statement
- Definitions
- Current Design
- Future Design
  - Multi-spectral Scene/Sensor Simulation
  - Virtualization of the Battlefield
- Considerations

VISION

Virtualization of the Battlefield

How It Fits Together



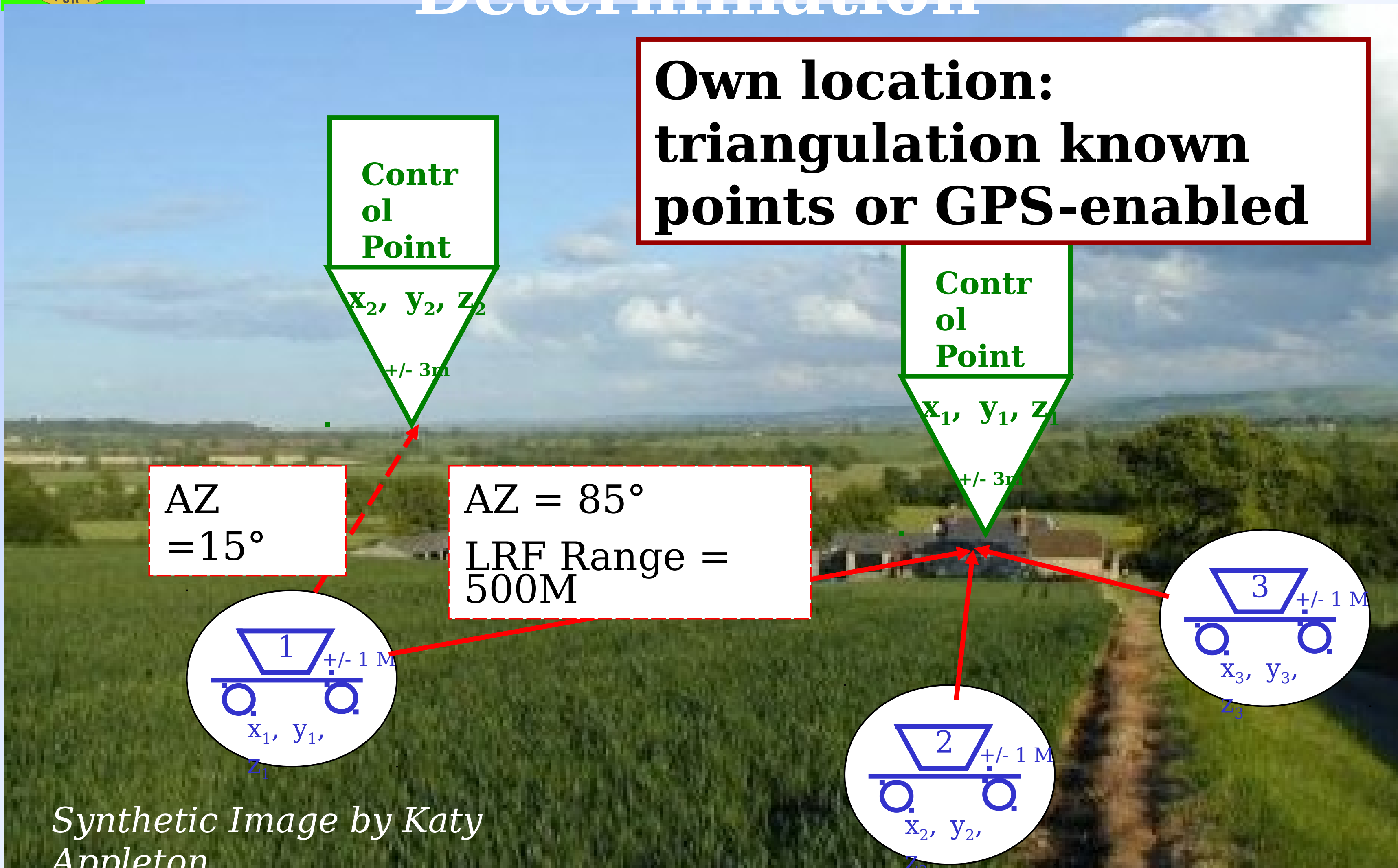
Geospatial Data Assumptions

- Source Data
  - DTED III - ~10 meter post spacing
  - Feature Data – Accuracy commensurate w/terrain data
  - 2x2 degree - ~1- 10 terabytes of data
- Geo-location System Accuracy After Calibration*
  - GPS location - ~1meter
  - Orientation - ~0.01degrees
- Need to examine alternate coordinate systems
  - Latitude-Longitude (WGS84 ellipsoid)
  - OTB Global Coordinate System
  - Objective OneSAF "Encapsulated Coordinate System"

* Virtual platform in simulation or real system in the field

Location Determination

Own location: triangulation known points or GPS-enabled



Synthetic Image by Katy Appleton

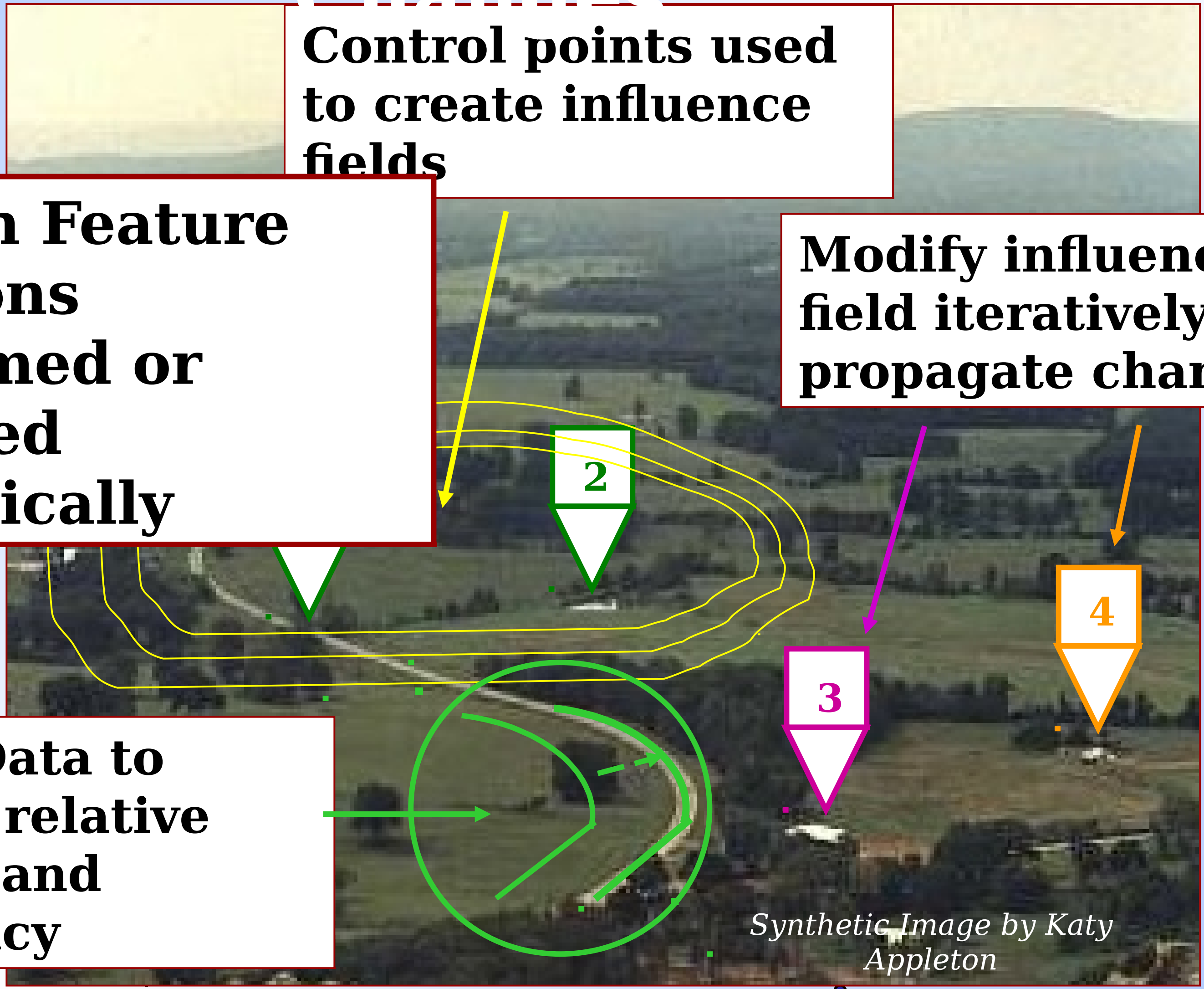
Dynamic Calculation and Tracking of Changes

Control points used to create influence fields

Terrain Feature locations confirmed or adjusted dynamically

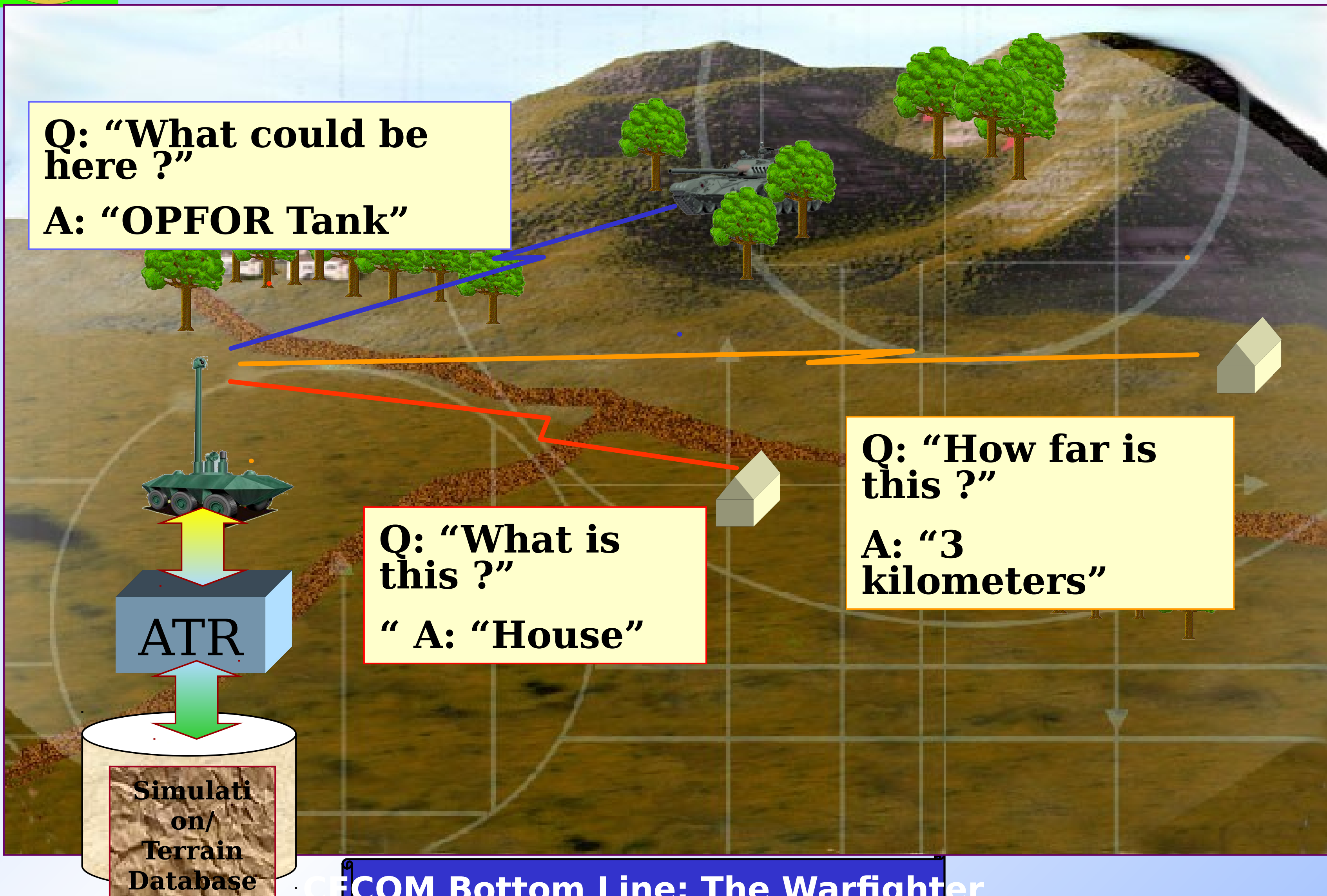
Modify influence field iteratively to propagate changes

Correct Data to maintain relative accuracy and consistency

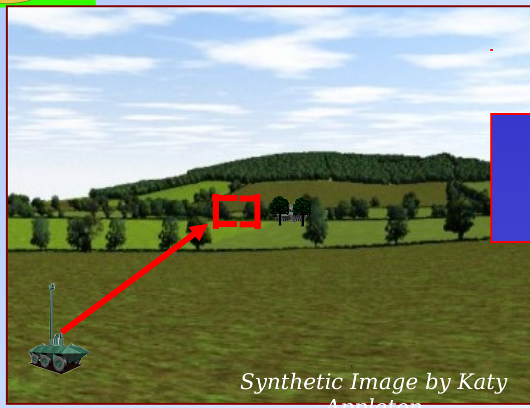


Synthetic Image by Katy Appleton

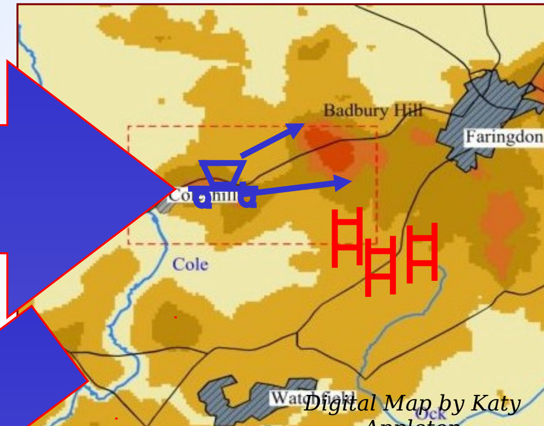
ATR Exploitation of Ground Truth Model



False Alarm Reduction

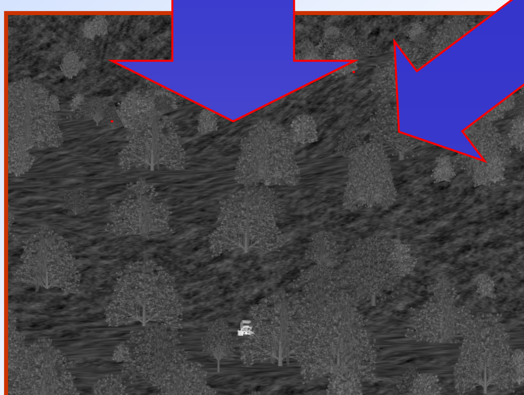


ATR Hits Suspected Target

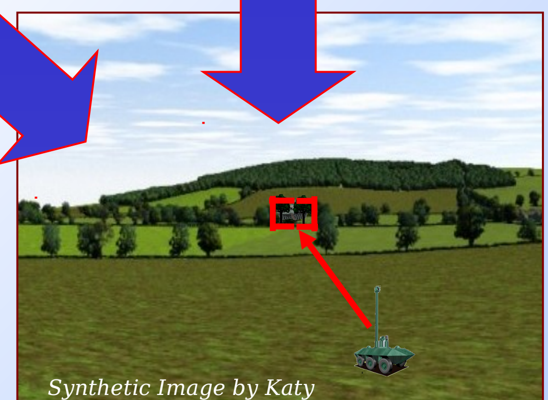


Query Database For C[illegible]cts

Confirmatio n Not Sufficient



Select Waveband



Retask or Move Sensor

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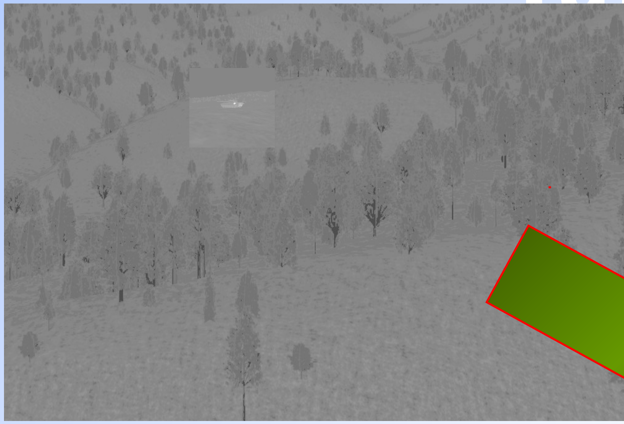
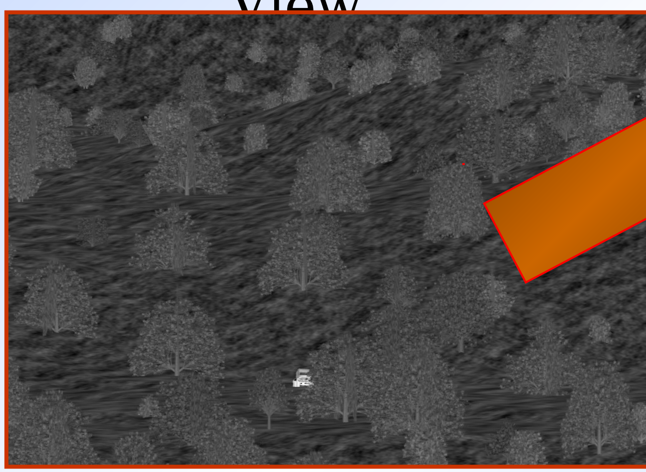
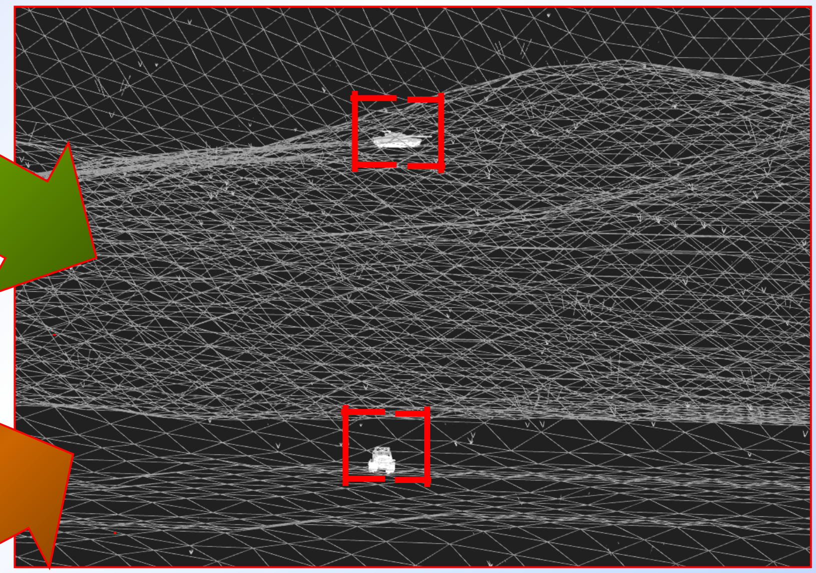
Ground Truth Model Used to Augment Targeting



First Sensor View

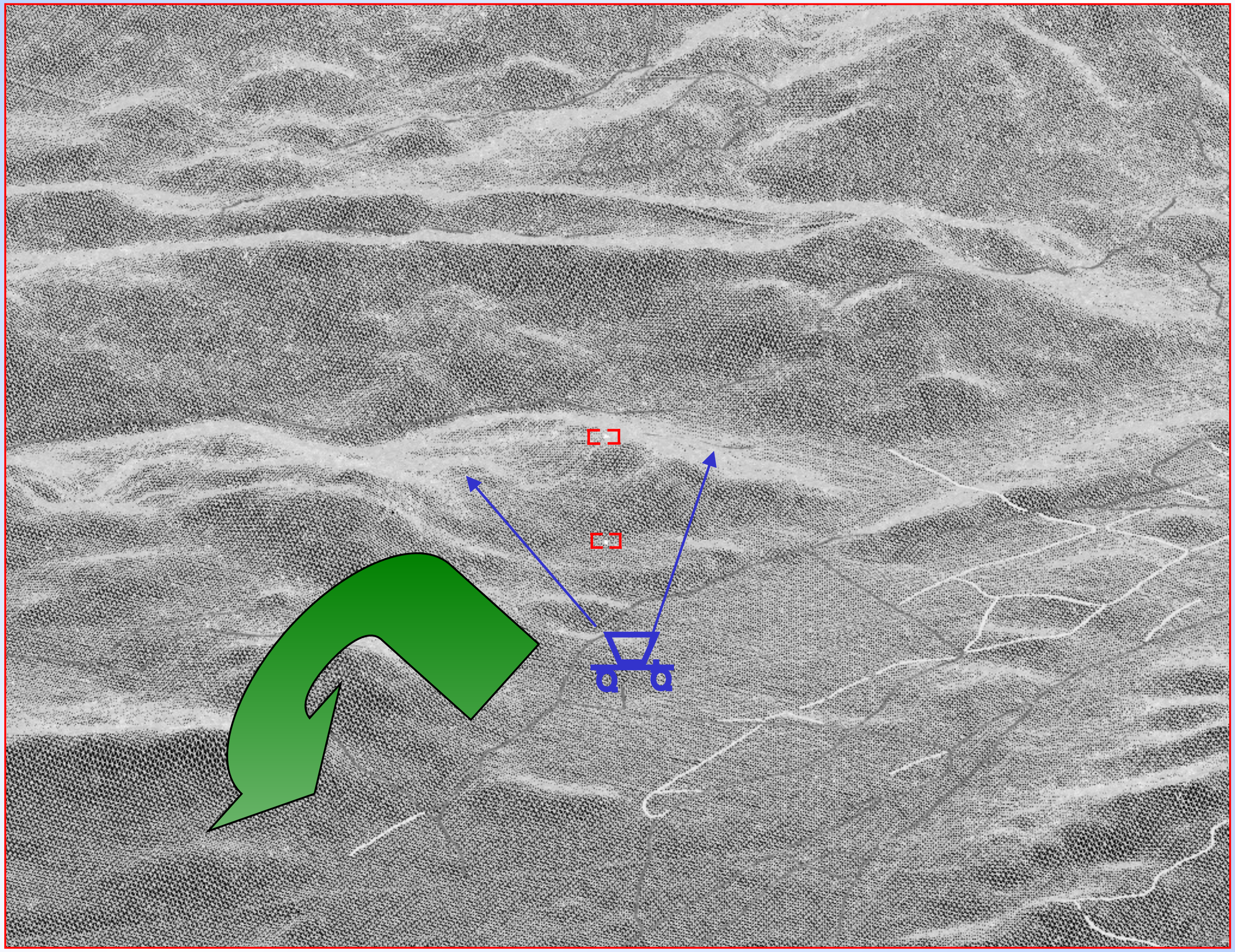


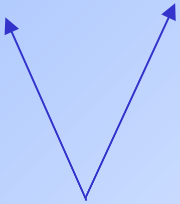
Second Sensor View



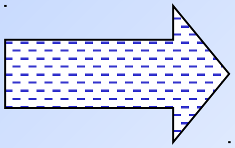
Simulation Enhanced View

TA Augmention: A Perspective View

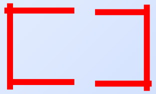




Sensor Field of View



Egress Route (Planned)



Target Detection

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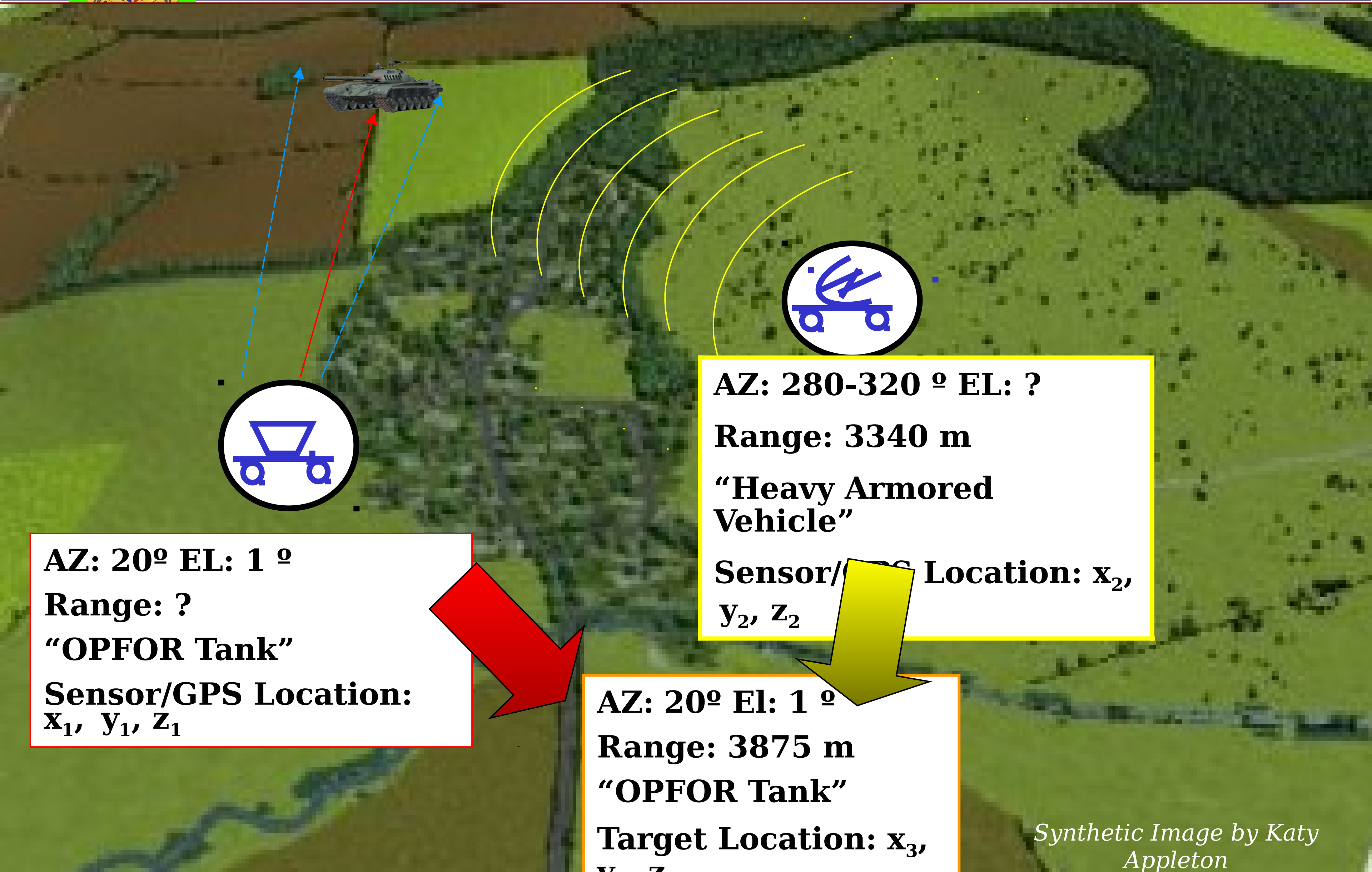
Multisensor Fusion



Synthetic Image by Katy Appleton

Problem Statement

A Grand-Challenge Computing Problem

- Realistic targets, enormous scene complexity, $>200Km^2$
- Physics-based hyper-spectral image generation
- Nano-atmospherics, smoke, and obscurants
- Ray-traced image generation, exact CSG geometry
  - Near-real-time (6fps)
- Fully scalable algorithms
- Network distributed MIMD parallel HPC
- Image delivery to desktop via ATM networks

Anticipated Uses

- Sensor Design Trade-offs
- ATR Training Development
- ATR and Target Acquisition Augmentation
- Obstacle Avoidance/Robotic Navigation
- Multi-Sensor Fusion
- Navigation w/o GPS
- Data Augmentation
- Mine Detection

Definitions

Characteristics of Composability

- Common Semantics and Ontology
- I/O is Well Defined
- Each Software Module Performs a Single, Well Defined Function
- All Results Must Be Available to the Backplane
- Has External Data Representation (XDR)
- Operating System Independent
- Transport Medium Independent
- Algorithm Independent or Neutral

Definitions

Ontology

1. <artificial intelligence> (From philosophy) An explicit formal specification of how to represent the objects, concepts and other entities that are assumed to exist in some area of interest and the relationships that hold among them. .
2. <information science> The hierarchical structuring of knowledge about things by subcategorizing them according to their essential (or at least relevant and/or cognitive) qualities. See subject index. This is an extension of the previous senses of "ontology" (above) which has become common in discussions about the difficulty of maintaining subject indices.

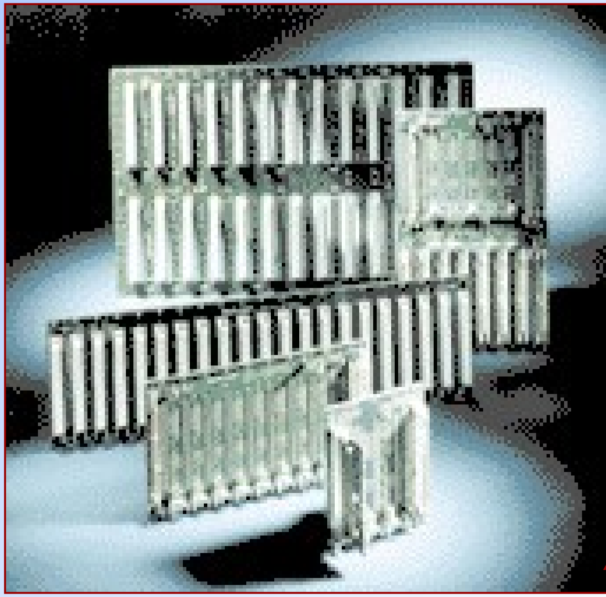
Semantics

1. Linguistics. The study or science of meaning in language.
2. Linguistics. The study of relationships between signs and symbols and what they represent. Also called semasiology.
3. <theory> The meaning of a string in some language, as opposed to syntax which describes how symbols may be combined independent of their meaning.

The semantics of a programming language is a function from programs to answers. A program is a closed term and, in practical languages, an answer is a member of the syntactic category of values. The two main kinds are denotational semantics and operational semantics.

Current Design

Backplane Architecture



BRL-CAD™ Ray Tracer

Next Generation Renderer

Target Acquisition/ATR Component

HLA with enhancements

Atmospheric Serv

Target Server

Terrain Server

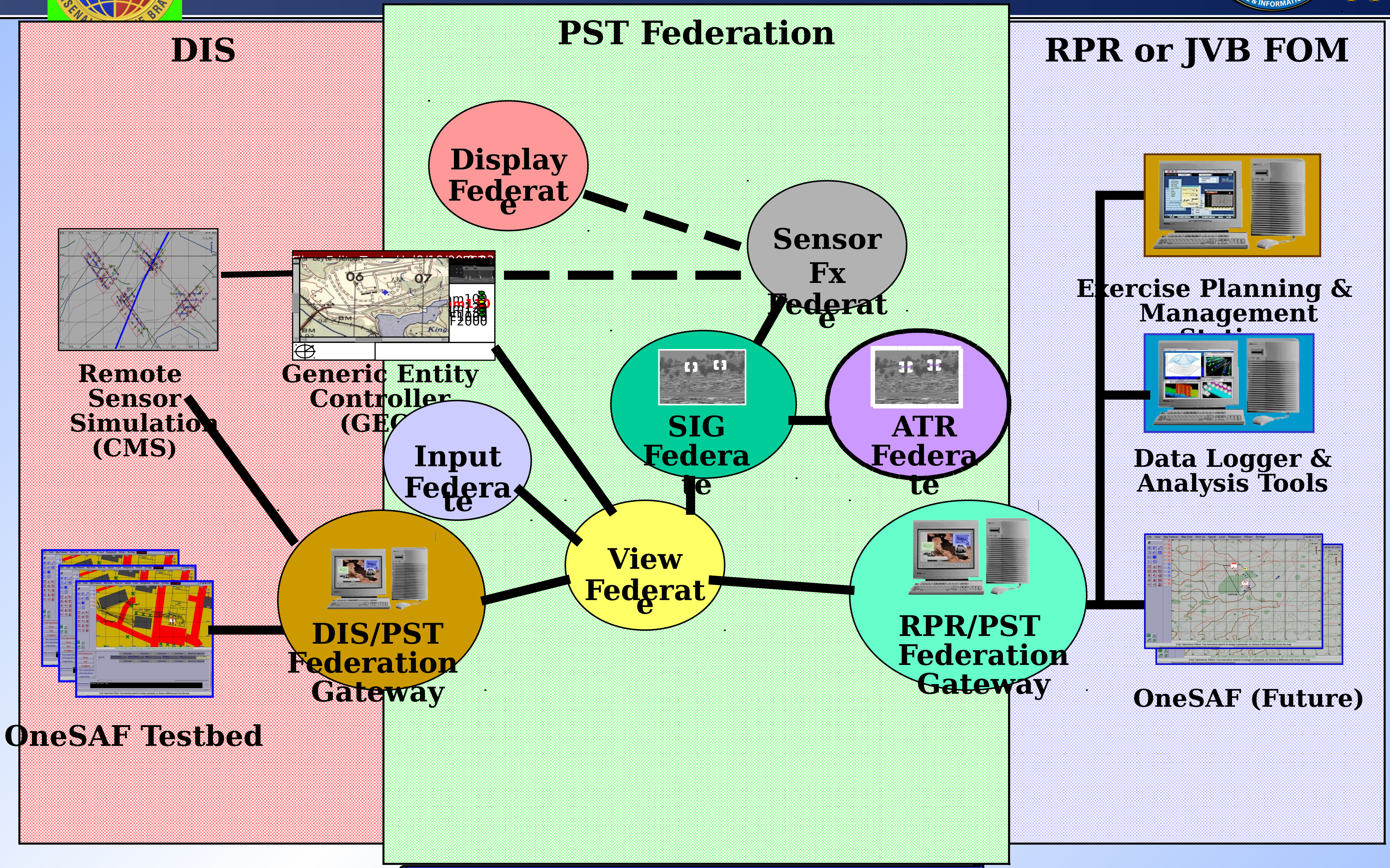
Thermal Models

:

:

- Standardized Slots
- Location independent

PTN System Architecture



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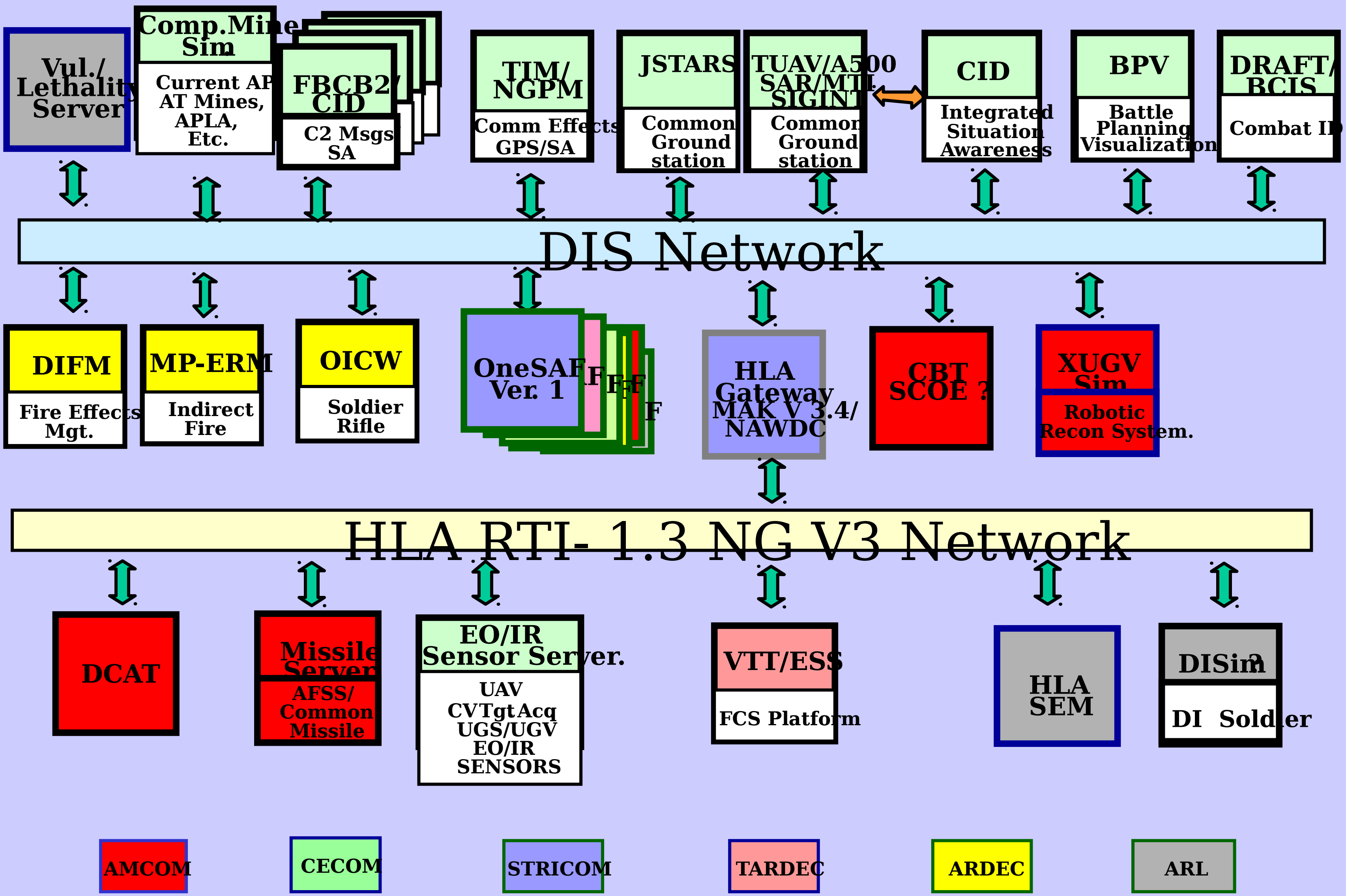
AMC RDEC Configuration



Future Design

Design Considerations

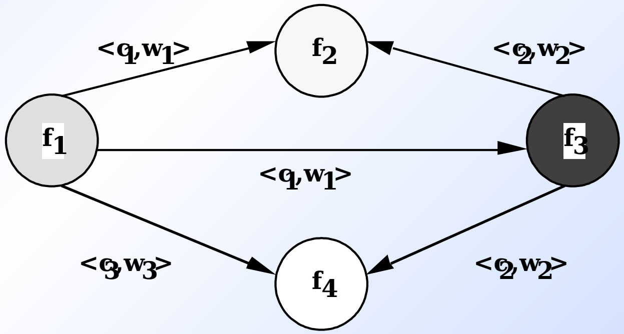
- Combination of Ray-tracing and Commercial Graphics
- HLA or HLA Follow-on Compliant Simulation
- Produces Data Able to Stimulate or Train ATR Systems, Prototypes
- Supports Multi-spectral, Hyper-spectral Waveband Fusion
- Supports Multi-sensor Fusion

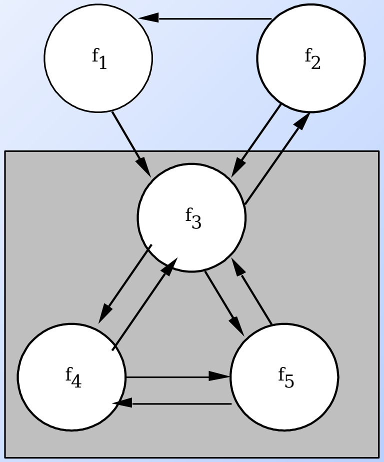
Design Architecture

- In Current PST System, the FOM is the SOM
- Future Approach Requires Accessible Objects at the SOM Level or below (A Composable Object Model ?)
- Backplane Architecture: Software Components that Are Portable, Distributable and Parallelizeable
- “HLA-like” with Multiple Transport Mechanisms (“Buses”)
  - All Software Modules Talk Through These
  - Transcends Current 1516 Specification
  - Allows for COTS Transport Media
- Publishers become Data Generators, Subscribers become Data Consumers, Bridges and Gateways and Data Servers Become Data Providers

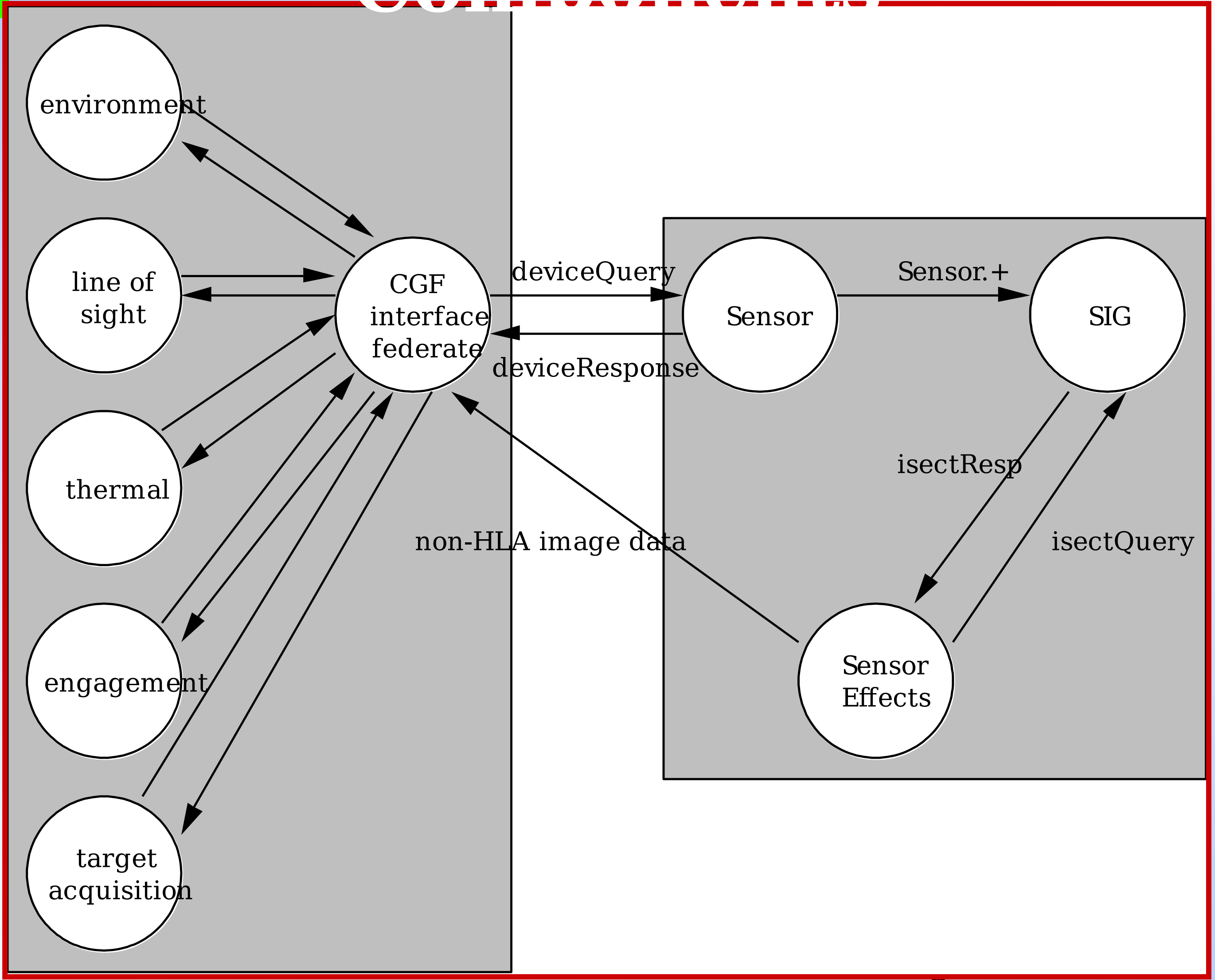
Peer-to-Peer vs. Composable Component

- Peer-to-peer federates:
  - They are logically complete and
  - They run on a single platform or
  - If they are distributed, their communication mechanism is generally not HLA.
- Composable component federates:
  - They are not logically complete,
  - They often don’t run on a single platform and
  - They are distributed using the Backplane as their internal communication mechanism.

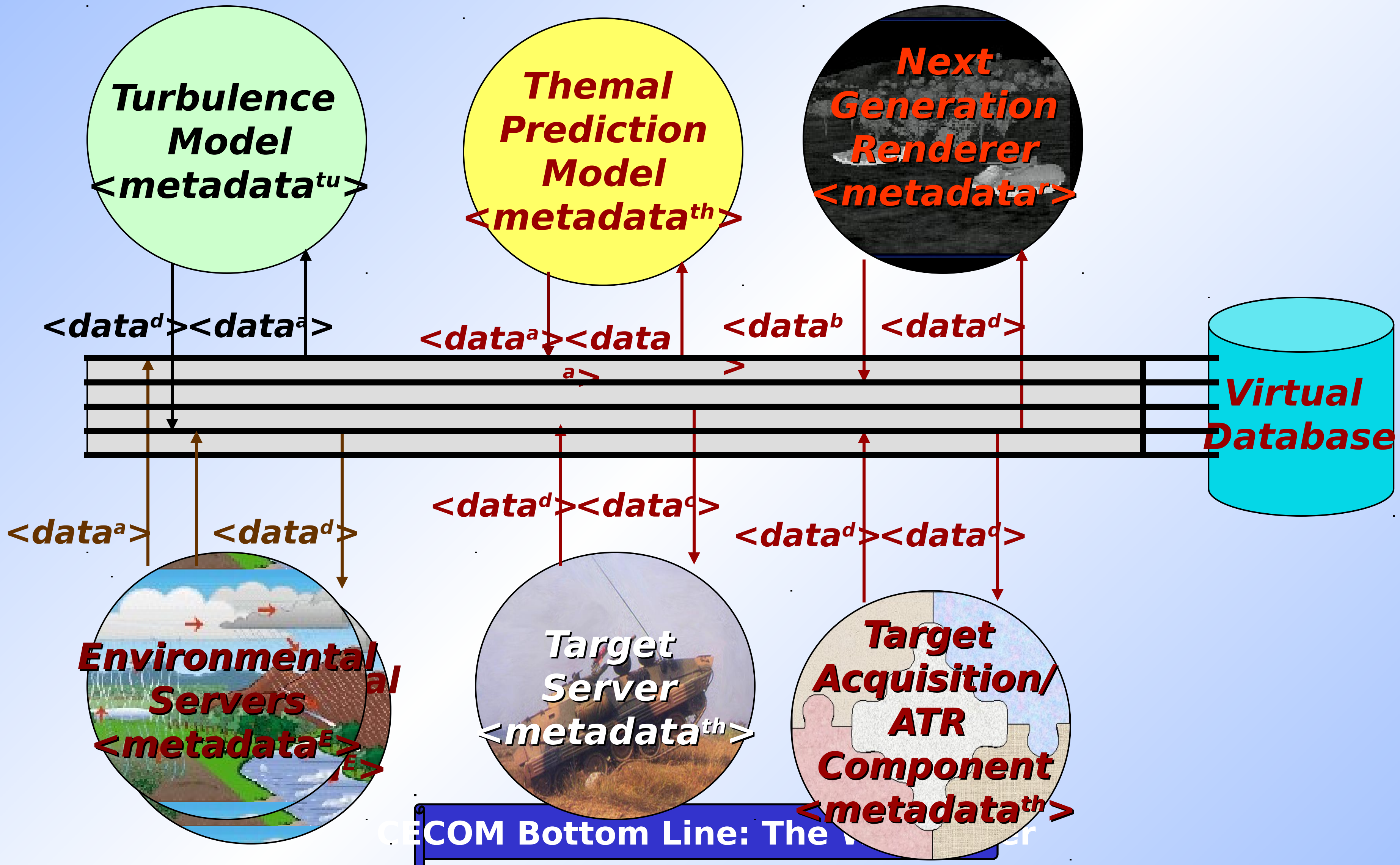




Notional Architecture w/ Sensor Simulation and CGF Components



Enhanced Backplane Architecture



CECOM Bottom Line: The

Composable Functions

External Data Representation

Well Defined Inputs in Well Defined Format

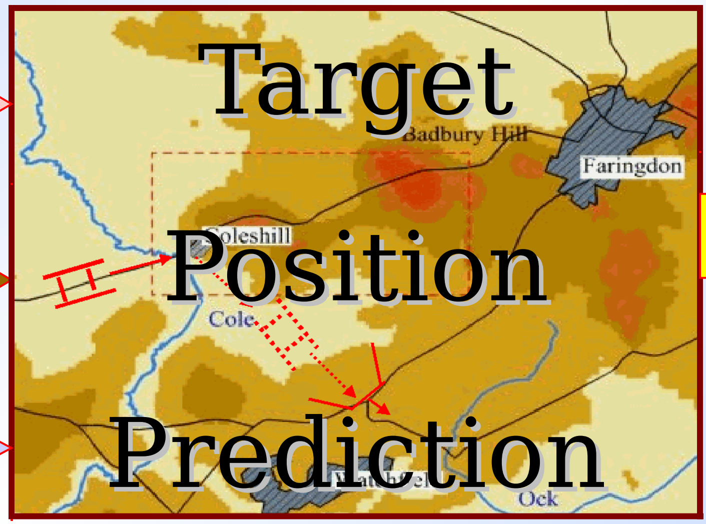
Well Defined Output in Well Defined Format

Last Target Observation

Ground Truth Model

Estimated Target Goal

Target Position Prediction



Target Position @ t+n

Next Generation Multi-Spectral Simulation

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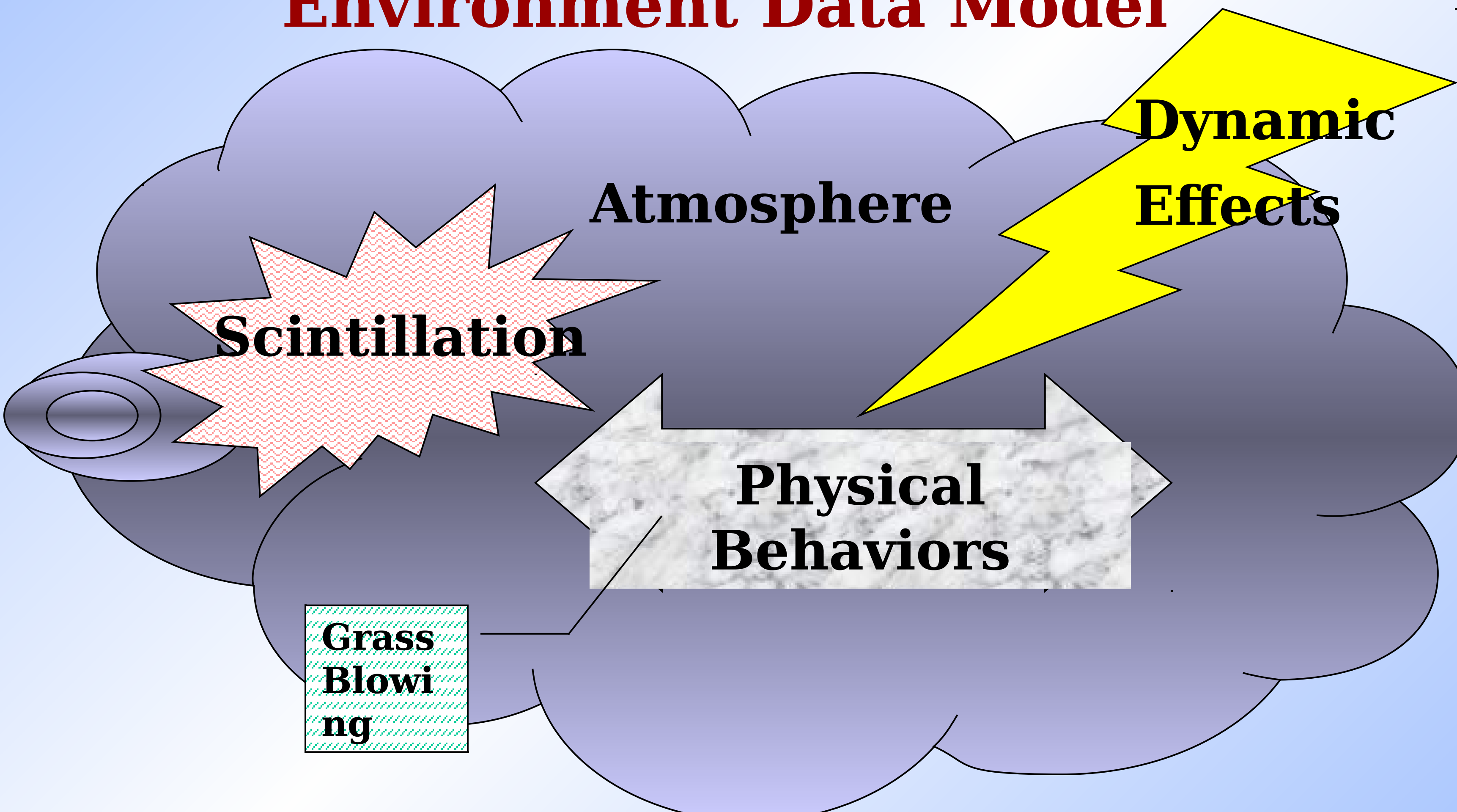
Goals

- Build a multi-spectral scene/rendering engine in support of 3rd/4th generation sensor design trade-offs
  - Multi-color
  - Waveband Coverage: .2µ to 20µ
  - Tunable Wavebands and Sub-bands
  - FPGA + Offboard Processor -> Accessible to ATR/Application
  - ATR/Wide Area Search
    - Tunable Detection Algorithms
  - Active Laser Illumination
  - Ability to Penetrate Clutter (e.g. FOPEN/LIDAR)

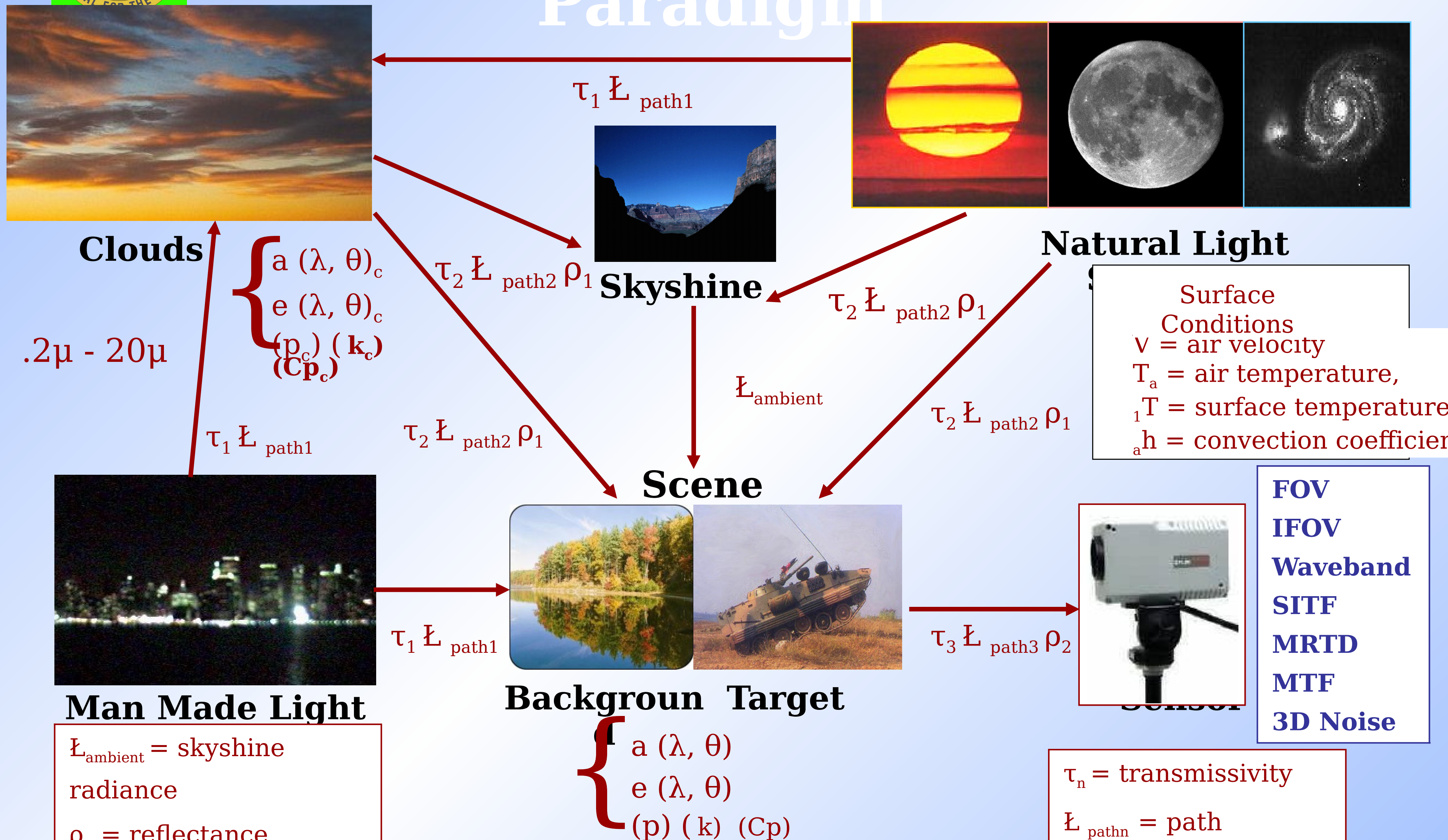
Synthetic Environment

Elaboration of 3d Gen/ATR Synthetic Environment Data Model



Environmental models are dynamic, complex and

Phenomenological Paradigm



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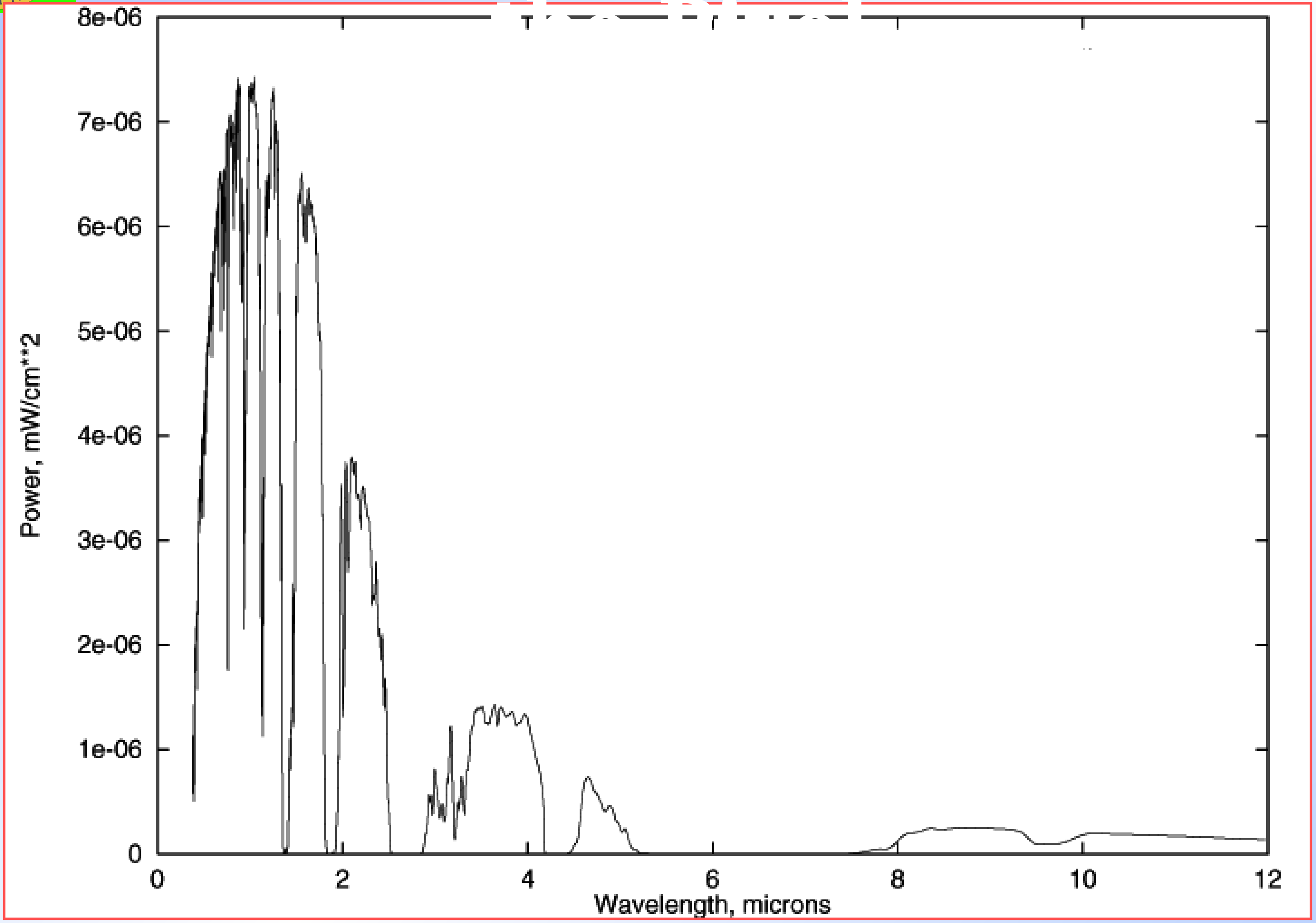
Hyper-spectral Ray Trace, The Power of the Pixel



Graph of the Power Spectrum of a Single Pixel

Considerations

Standards: Languages, Databases, Tools

- Existing Language Standards Supplemented By Best Practice Guides
- Integration of OS Independent Commercial Tools (e.g. UML, XML) with HLA and SEDRIS Technologies
  - Need to Eliminate Redundant Designs
  - Need for Interchange Among CASE Environments (e.g. OMDT, Rational Rose™, XML Spy™)
- Databases Built to the Highest Fidelity, with Easy Access to Only What Is Needed

– "Authoritative" Databases Need to Provide Adequate Ground Truth

User Interface Issues

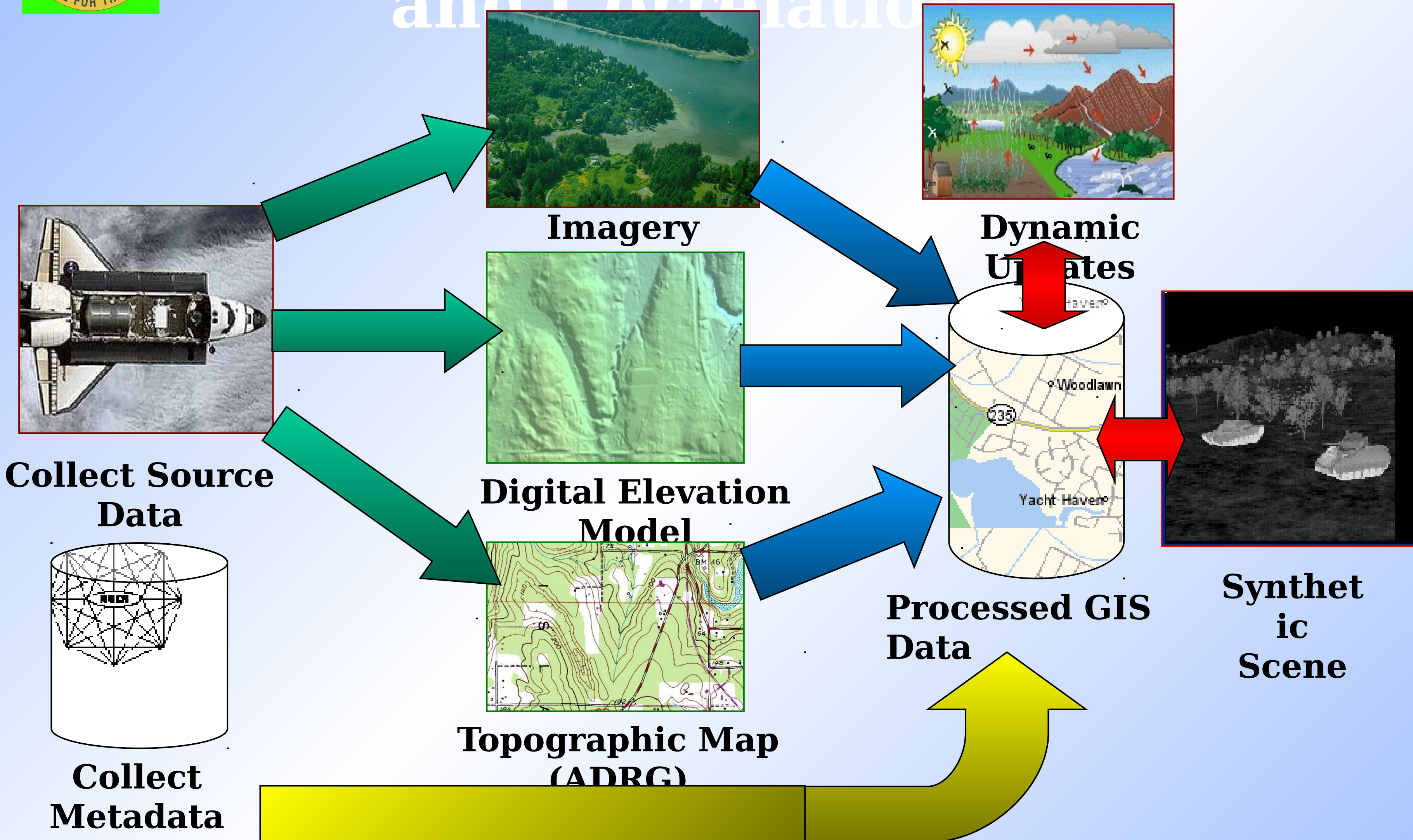
- Develop set of glyphs that warfighters can use
- Glyphs are icons that represent functions or capabilities
- Example: Cantata (khoros)

Concluding Thoughts

- A composable application is difficult to develop, but powerful once done
- DREN should be the network used, need to have a configuration dedicated to simulation
- Networking considerations
  - Bandwidth
  - Latency
  - Jitter

Backup Slides

Environmental Data Collection, Mensuration, and Correlation

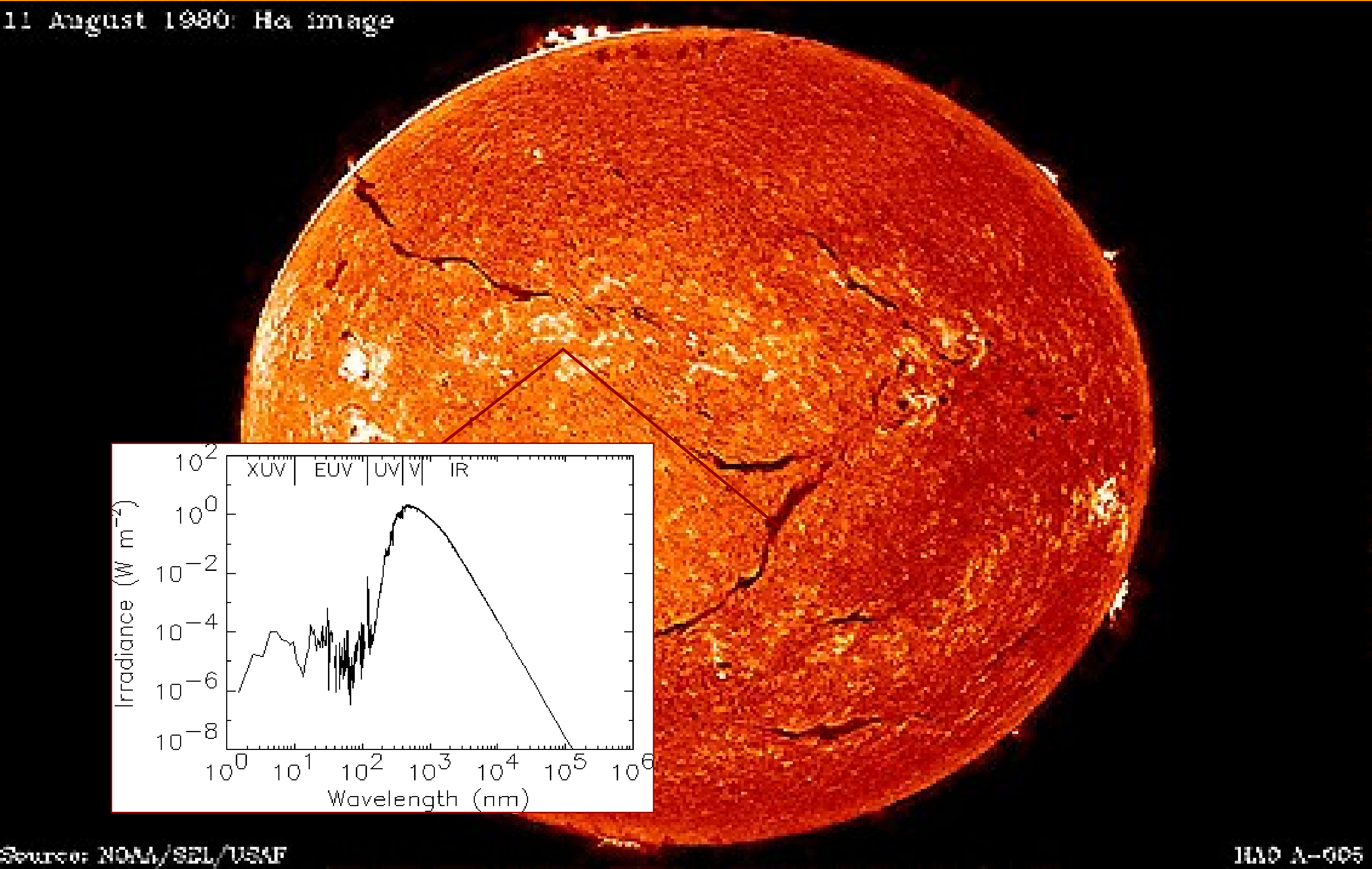


CECOM Bottom Line: The Warfighter

Software/Toolsets

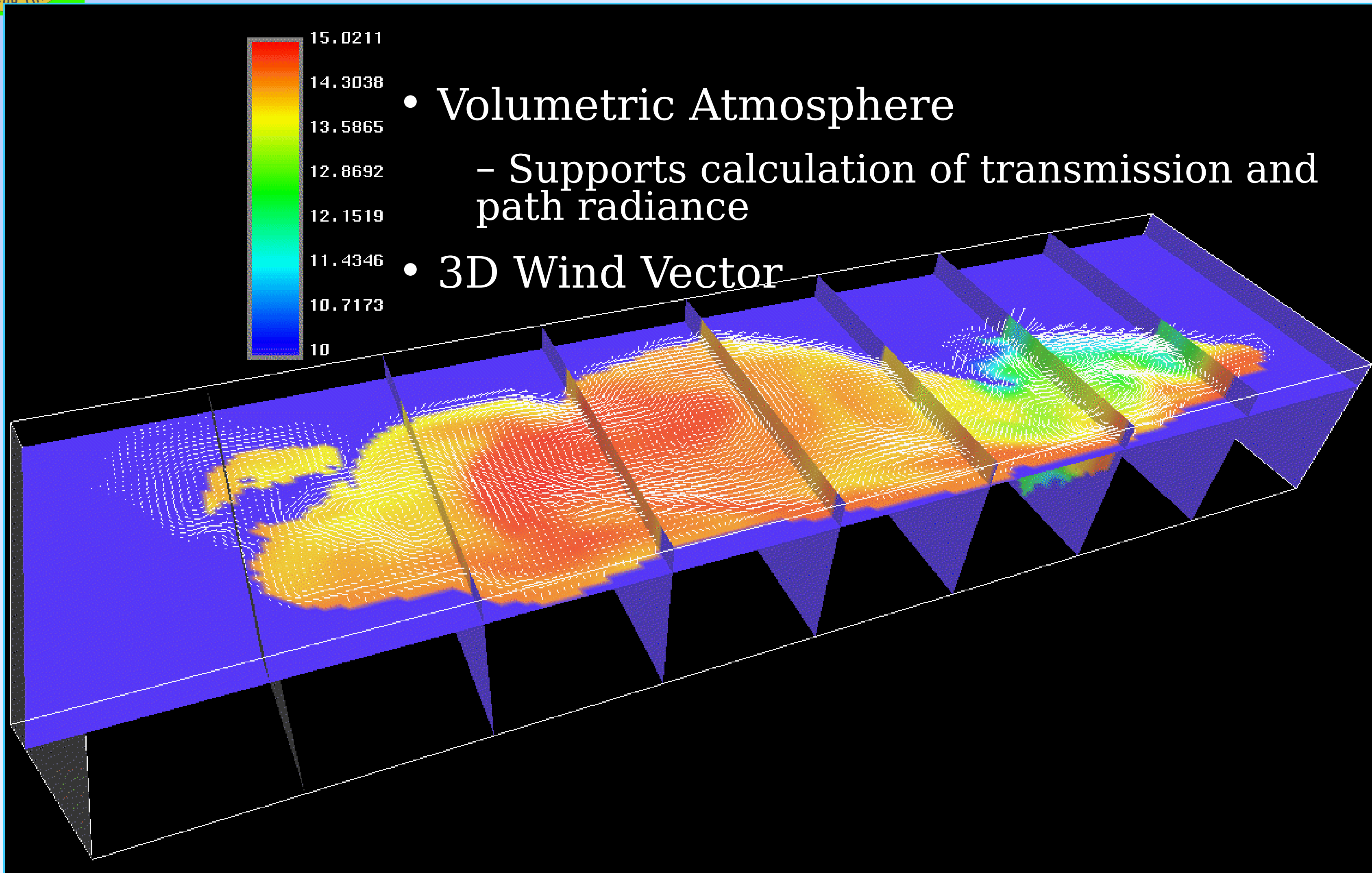
- Terrain Build
  - Upgrade TerrainGen for Raytracer
  - Procedural Terrain and Objects
  - Interactive Terrain Update
- Target Build
  - BRL CAD Native & NMG
  - Maya with plug-ins
- Physics model plug-ins
  - Thermal solver
  - Atmospherics
  - BRDF renderer
  - Vehicle dynamics
- Scenario Build
  - OTB
  - Standalone Target Generator
- Sensor/Image Generator
  - Geometry Processor
  - Sensor Effects
  - Target Dynamics
  - Dead Reckoning
- Scene Snap

Solar Radiation

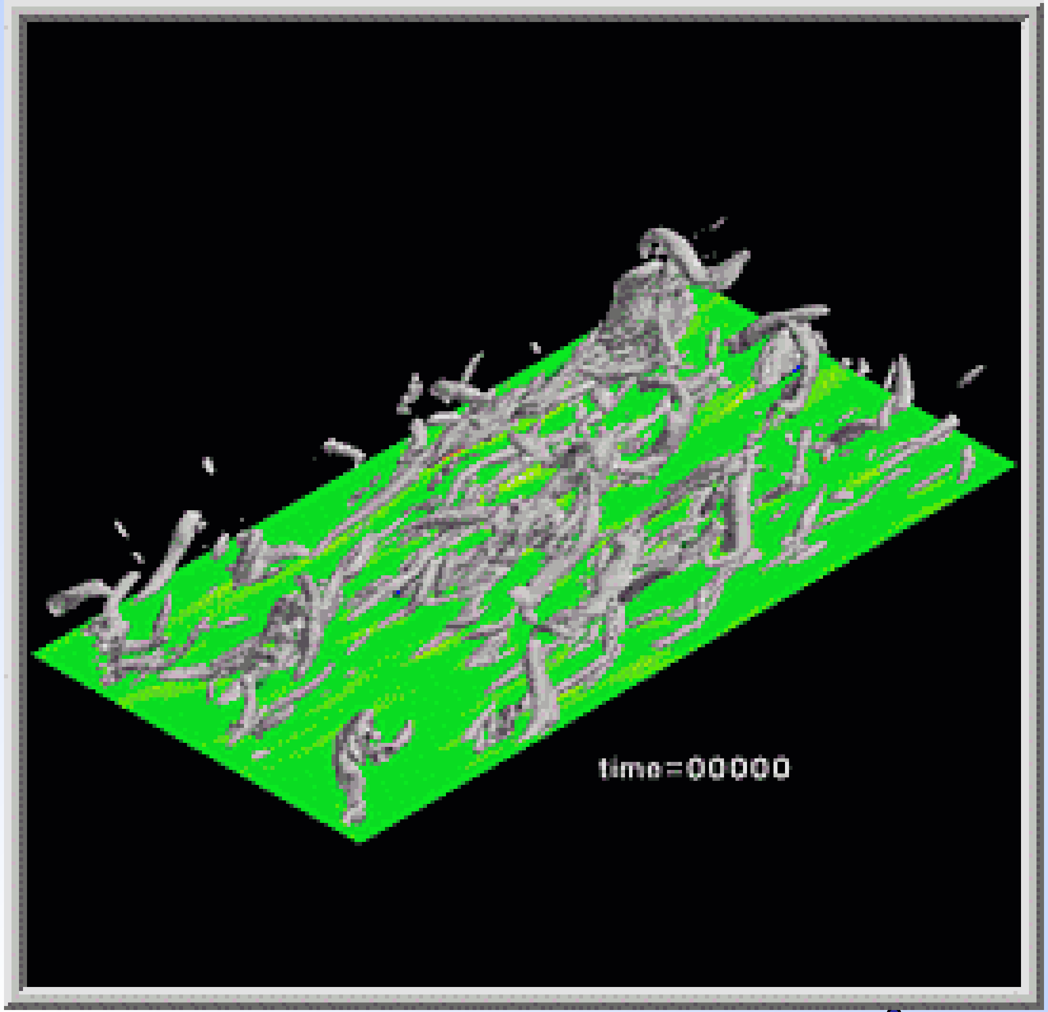


3D Atmosphere

- Volumetric Atmosphere
  - Supports calculation of transmission and path radiance
- 3D Wind Vector



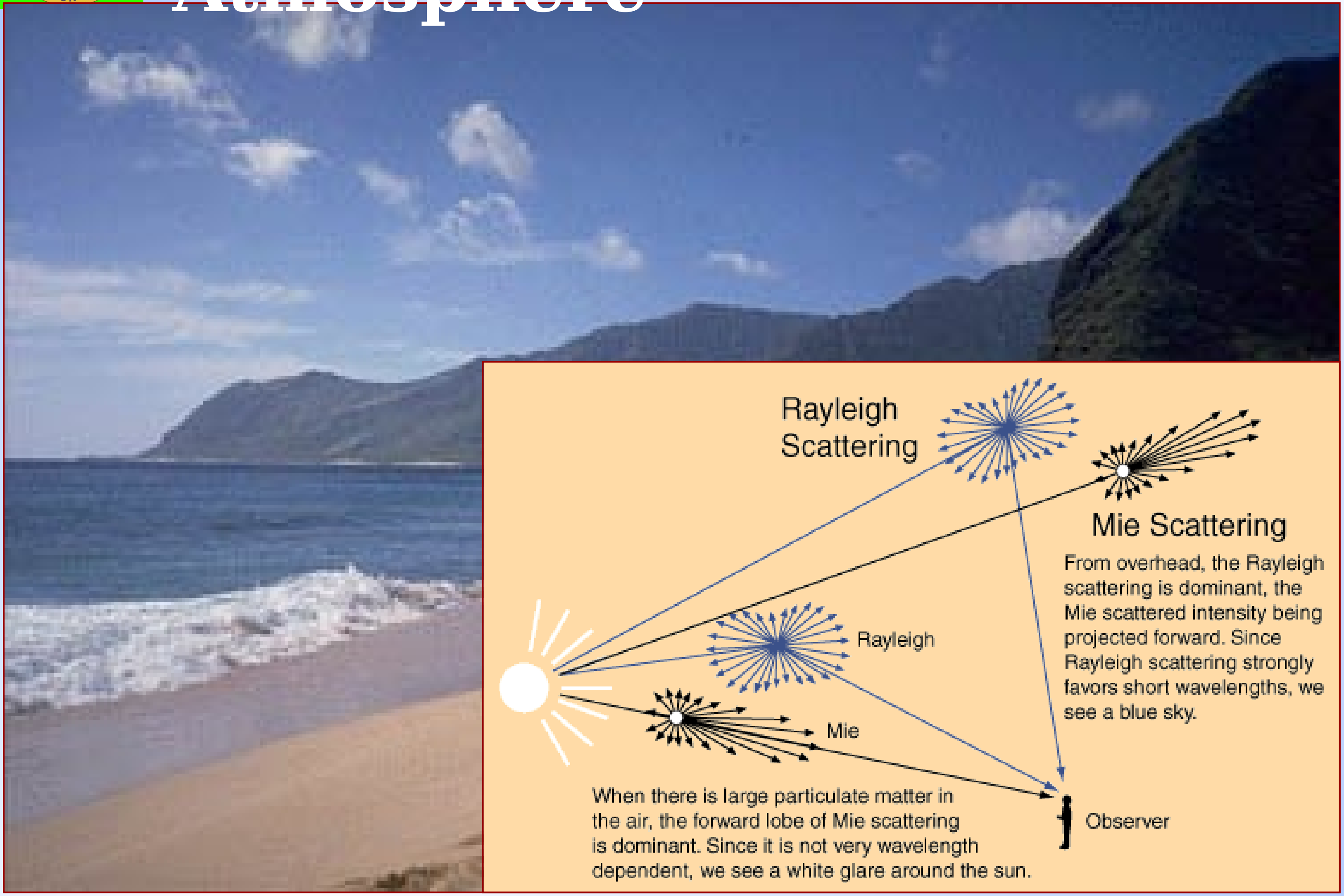
Turbulence



Smoke and Obscurants

Paint the Night Scene w/ COMBIC Smoke

Scattering from the Atmosphere

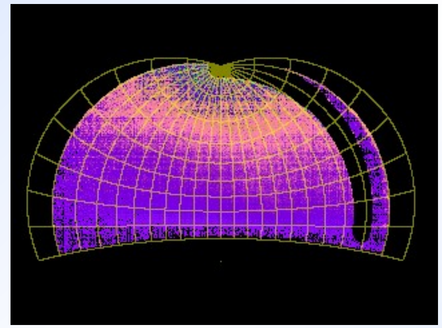


Emission and Reflection

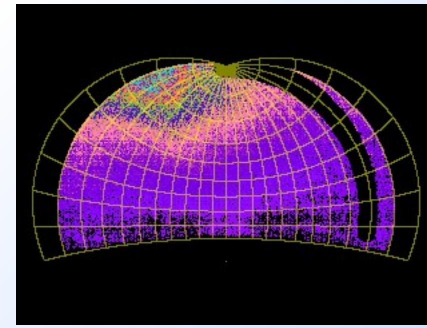
Thermal Imager, Courtesy CECOM/NVESD

Reflectance Database

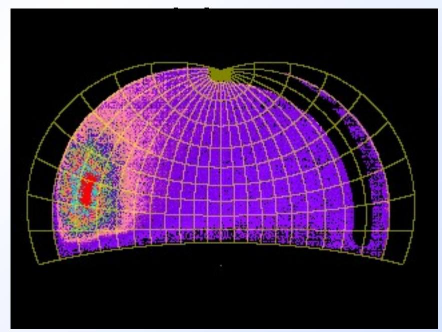
F-1: Road Gravel, Undisturbed



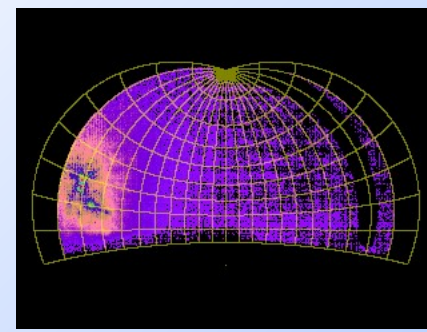
Mid IR, 10°



TIR, 10° Incidence



Mid IR, 60° Incidence



TIR, 60° Incidence

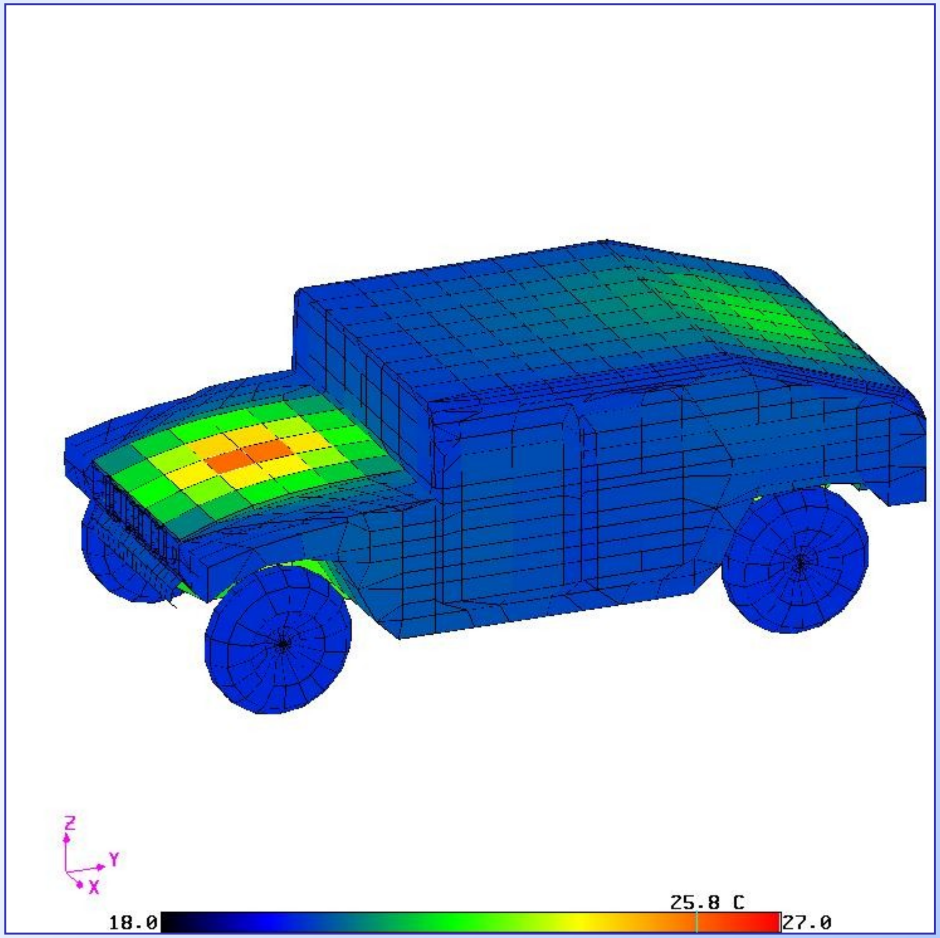
Directional Hemispherical Reflectance (DHR) & Bi-directional Reflectance Distribution Function (BRDF) measurements in Visible, Mid-IR, & Thermal IR (TIR) 34 natural & man made materials found at Ft. A.P. Hill.

Background Components

Procedural Grass Courtesy of Lee Butler, ARL

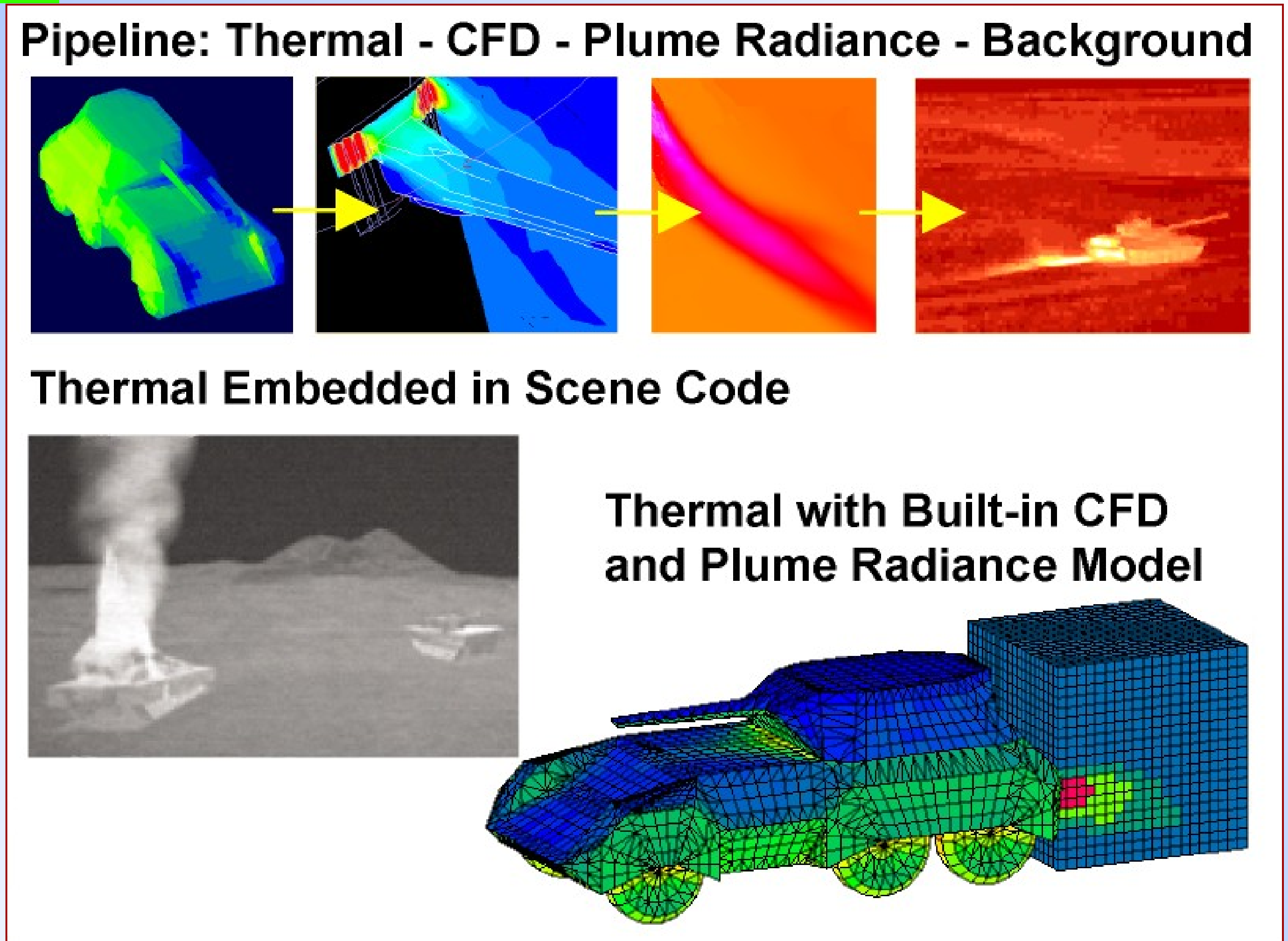
MUSES

- Target signature developed using Muses thermal modeler
- Target signatures will still use real imagery, but only to provide detail.



Courtesy TACOM

Target Interactions



Courtesy TACOM

Issues

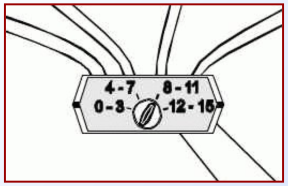
- Multi- and Hyper-spectral Scene/Sensors
  - BRDF
    - Measurement
    - Rendering
  - Shadows
  - Thermal Solver
  - Sub-Waveband Signatures
- Scene Complexity and Clutter
- Atmospheric Representation
- Target Environment Interactions

Hardware Requirements

Linux Cluster IA64
- 32 processors/Cabinet
- 64 Gbytes RAM/Cabinet
- 256 Gbytes Swap/Cabinet
- 4 Terabyte RAID system

Linux Cluster IA32
- 12 units (4)
- 4 processors/unit
- 4 Gbytes RAM/unit
- 16 Gbytes Swap/unit
- ATM OC-3
- 1 Video Board/unit

Server
- 4 processors
- 4 Gbytes RAM
- 16 Gbytes Swap
- ATM OC-3 and OC-12
- 4 Terabyte RAID system
- DSP



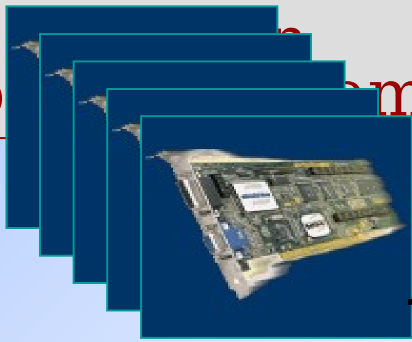
ATM Switches
- 8 ASX200-BX switches (3)
- 1 OC-12 Netmod/switch (1)
- 3 OC-3 Netmods/switch (1)
- 1 OC-12, 12 OC-3 (1/4) connections/switch

Graphics Processing Architecture

Single cluster

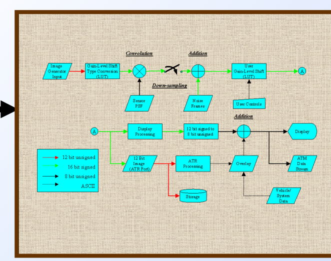
3.0 million polygons/frame@30Hz

1
p me@60Hz

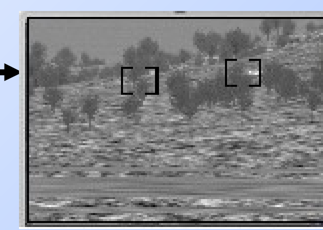


Video Cards (12) (250K polygons/frame/card)

Alpha Channel Matte



Sensor Effects/ ATR

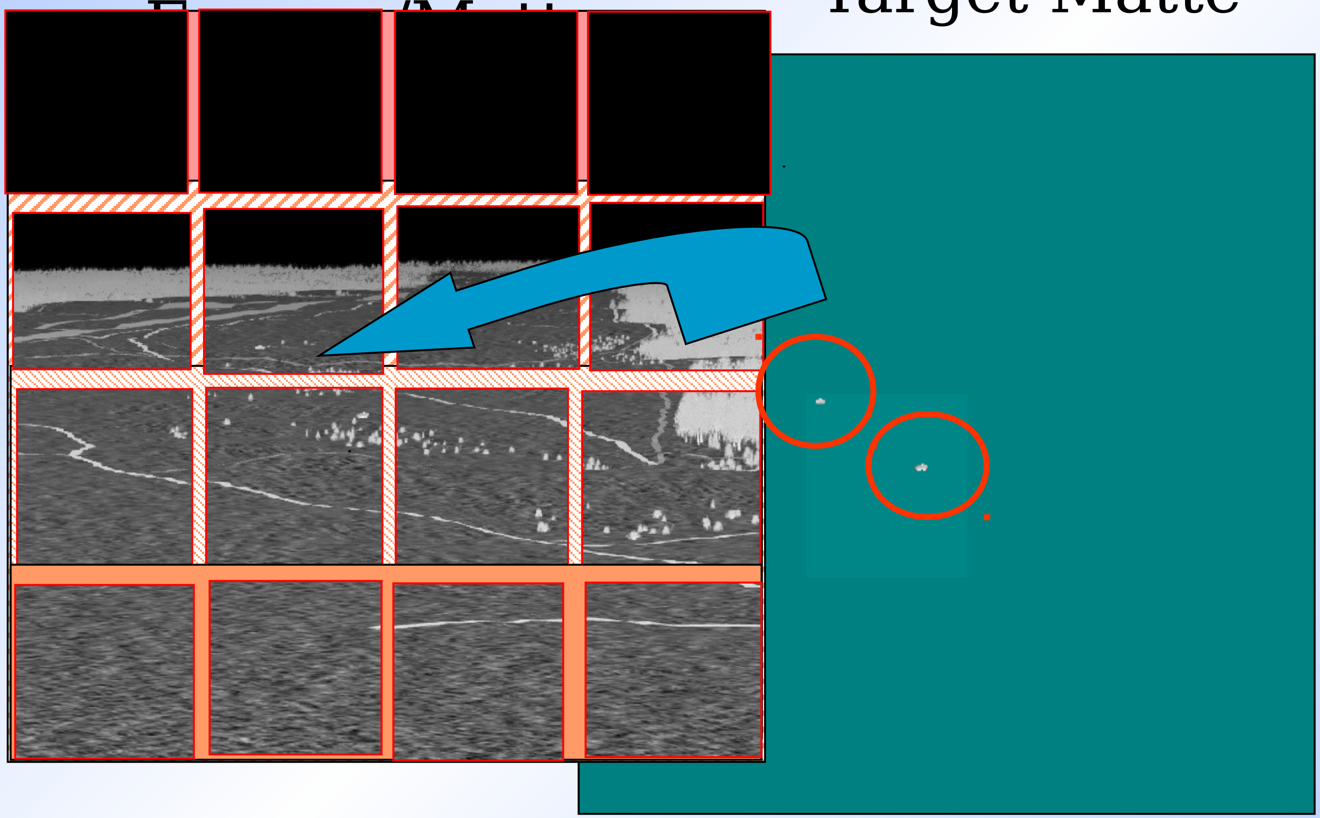


Display

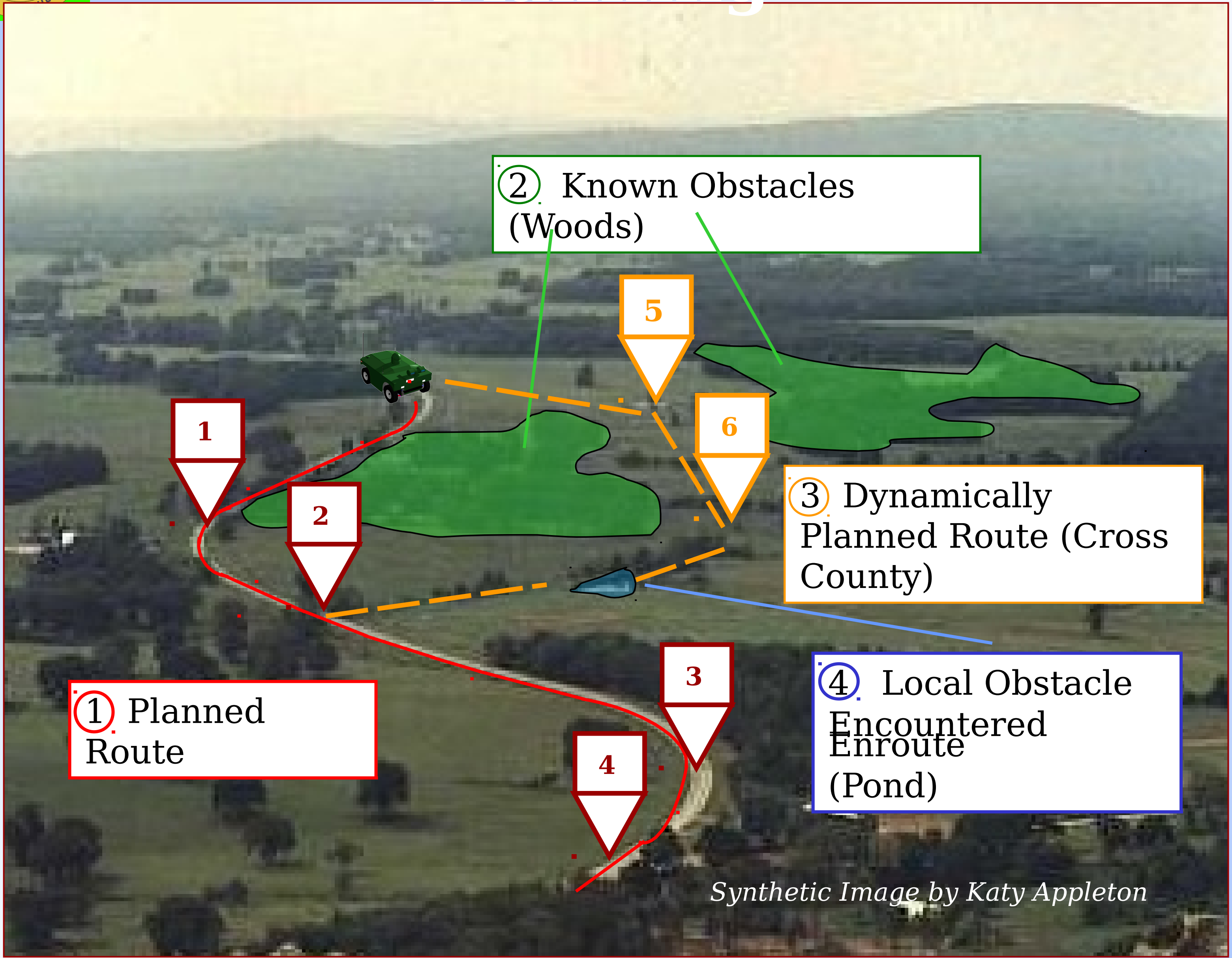
Video Matte

Background

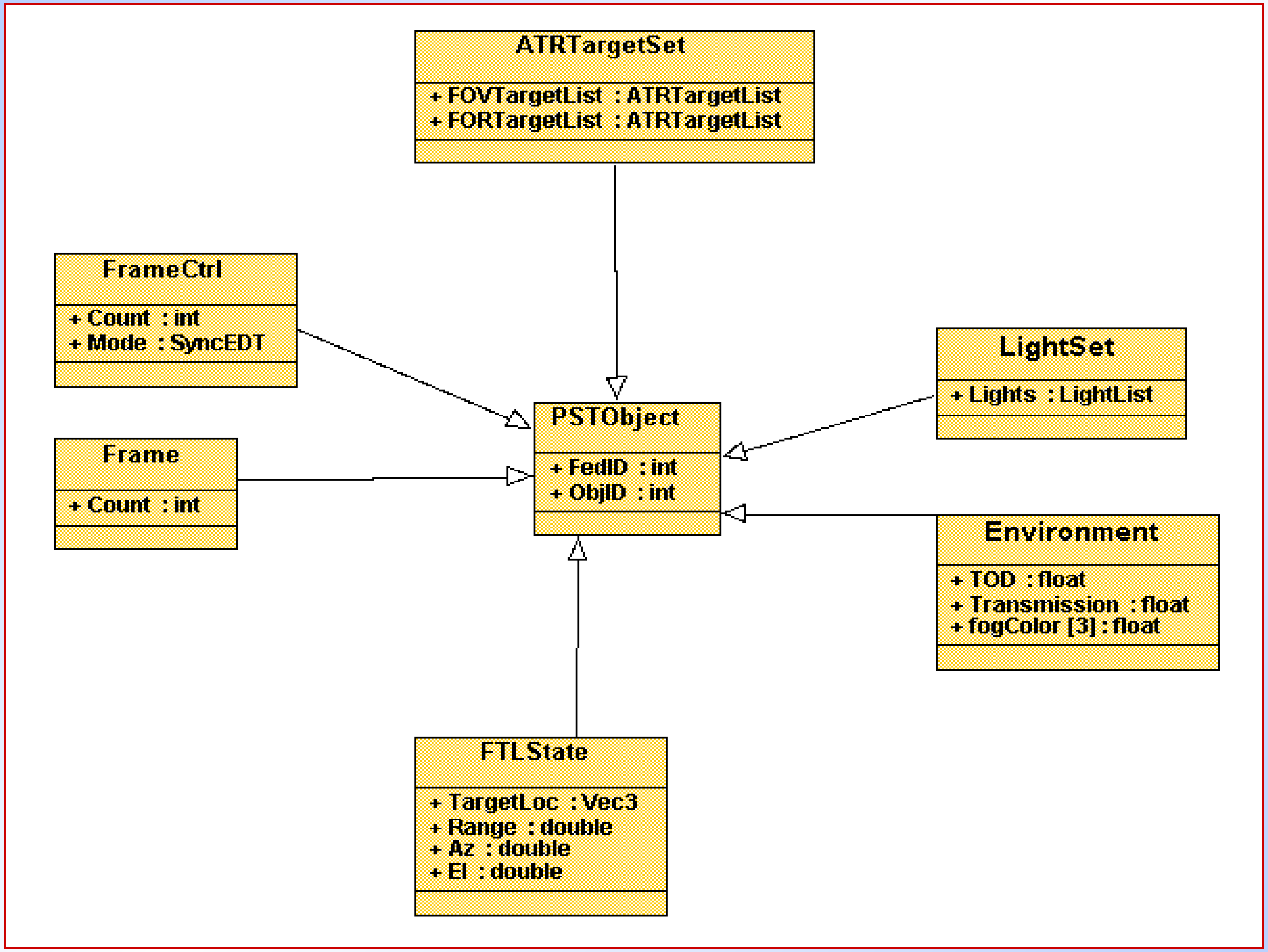
Target Matte



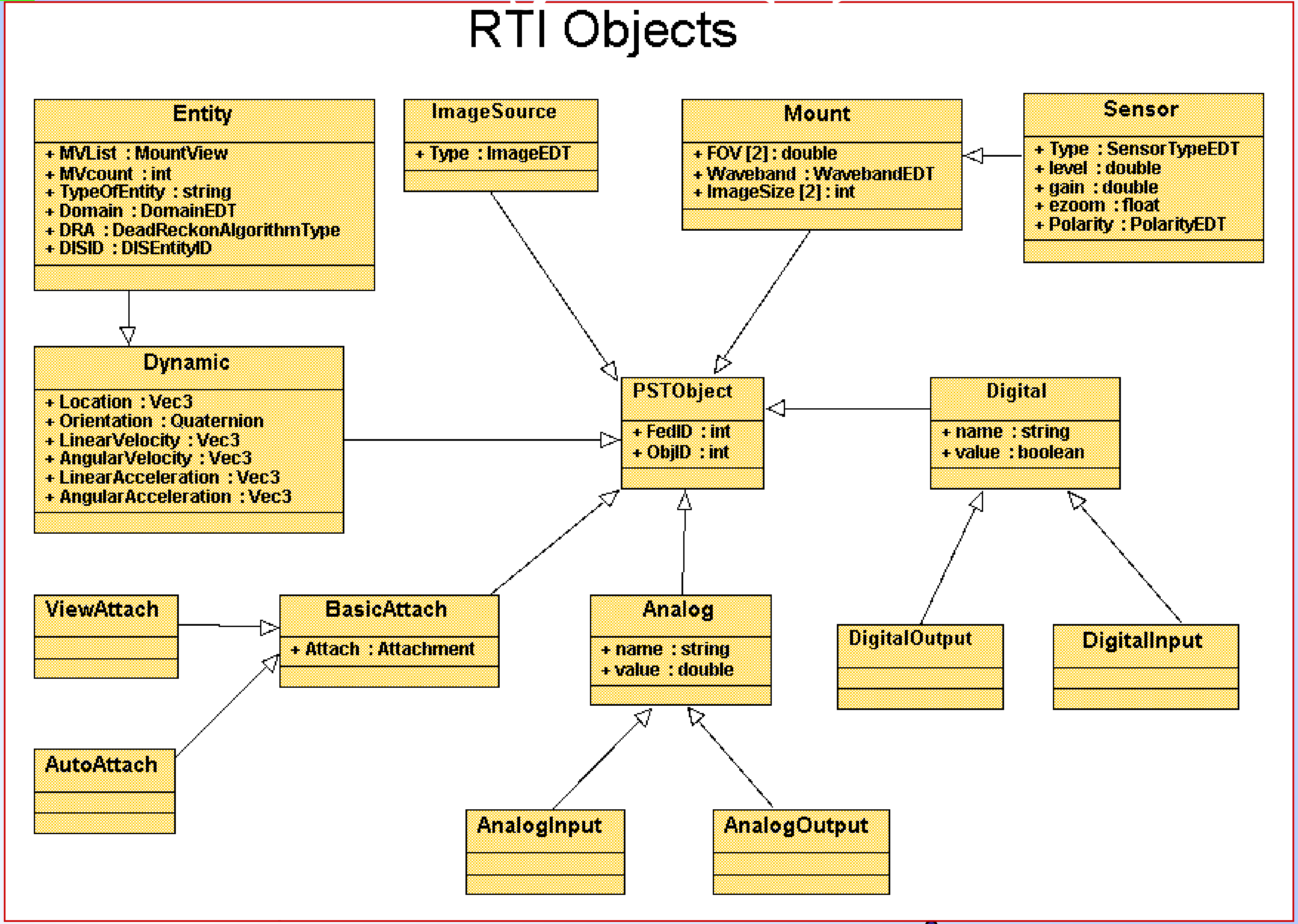
Autonomous Route Planning



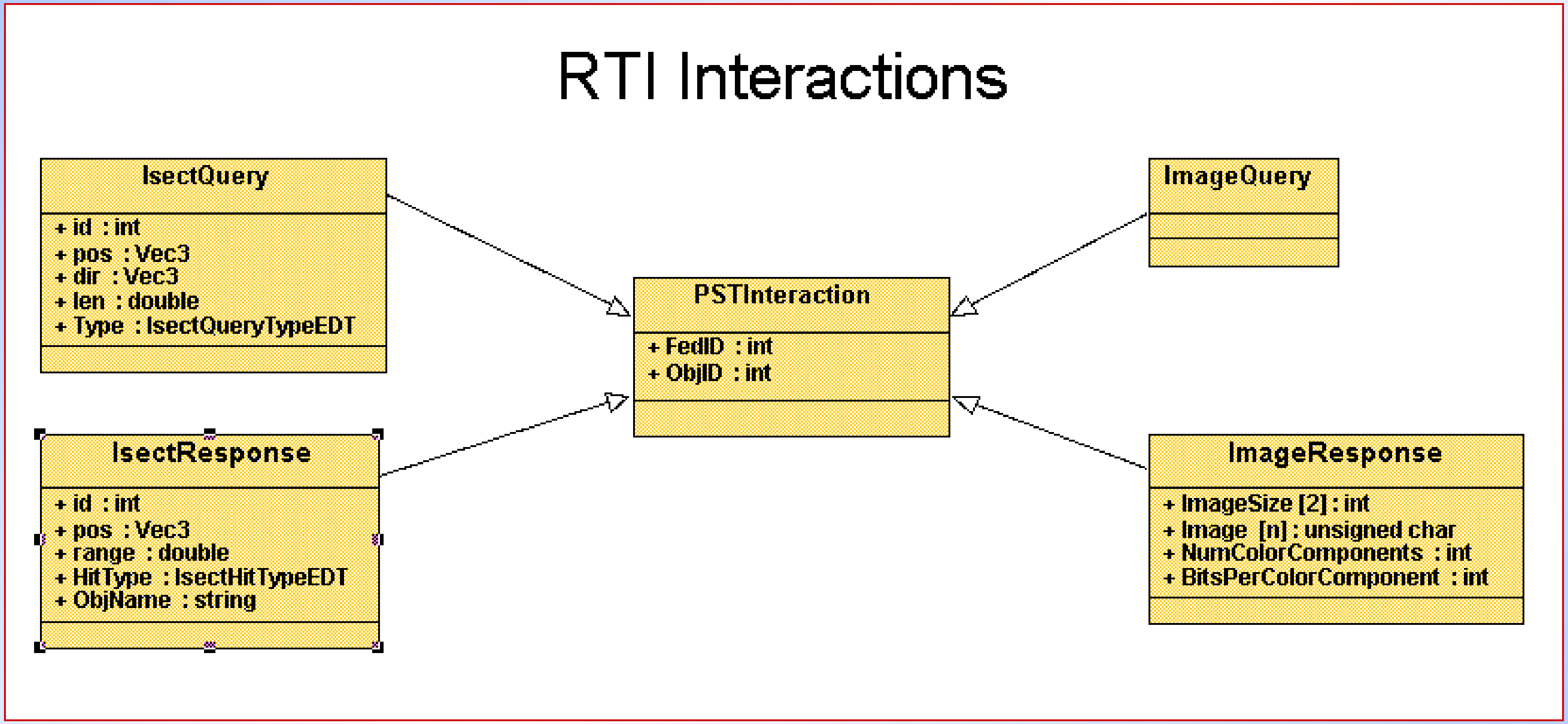
PST Federation Class Diagram (2)



PST Federation Class Diagram (1)



PST Federation Interactions



PST Federation Data Types